Smarter Irrigation for Profit - Increasing farm profit through efficient use of irrigation input to dairy pastures

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Smarter Irrigation for Profit - Increasing farm profit through efficient use of irrigation input to dairy pastures

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Abstract

The dairy industry is the second largest user of irrigation water in Australia. Increasing competition, climate variability and costs of irrigation water, along with reduced water availability are driving farmers to adopt innovative practises and technologies that utilise water as efficiently as possible. The average water usage of Australian dairy farms is 6.3ML/ha, with each ML generating a value of approximately $430. Over 75 percent of the dairy farms in Australia are pasture-based systems. In spite of this fact, and the importance of pasture utilisation in pasture-based dairy systems, pasture utilisation across the industry has remained at 50-60 percent of what is potentially possible. Effective management of the spatial and temporal variability in water demand is viewed as the key to optimising pasture production. Automated precision irrigation is now possible with the deployment of cheap sensors, crop models, and irrigation control systems bundled in appropriate built-in technology. This significant step change in irrigation system capability offers an opportunity for a significant improvement in irrigation performance for all irrigators. This paper provides an overview of how detailed monitoring of five intensively managed irrigated dairy farms in Tasmania is being used to review and enhance industry performance benchmarks. It is aimed to use the outcomes of this work to increase the adoption of enabling practices and new technologies for pressurised irrigation systems in pasture based dairy systems.

Introduction

According to the 2013-2014 ABS Water Account, the dairy industry is the second largest user of irrigation water in Australia (ABS, 2015); utilising 307,900 ha of irrigated land. Increasing costs and questions concerning consistency of water supply are major concerns for dairy farmers. Thus there is a pressing need for industry to develop and adopt innovative practices and technologies to maximise water use efficiency. Effective management of the spatial and temporal variability in water demand is viewed as key to optimising production (Greenwood et al. 2010). Whilst system design and new technologies have improved in recent times, early adopters of new technology often find it difficult to capture all the possible production improvements. Thus early adopters can struggle to justify investment in the new technology.

This project addresses ongoing requirements to improve irrigation management and water use efficiency, and thus the sustainability and profitability of irrigated dairy systems in temperate environments. These targets need to be achieved while also protecting soil resources and minimising environmental impacts.

The project aims include:

a. identifying key irrigation system modifications and practices that can be efficiently and effectively adopted to achieve improvements in energy, water use efficiency, pasture production and returns per ML of irrigation applied

b. quantifying the benefits of adaptations that minimise the occurrence of water logging and nutrient losses

c. quantifying the performance of autonomous sensor based pressurised irrigation in pasture-based dairy systems with respect to: pasture productivity, irrigation performance, labour and management savings

d. developing information resources for the dairy industry that enhance irrigation scheduling decisions, improve understanding of uniformity, system design and key energy saving approaches for pressurised irrigation systems.

Methods

Sites

Five sites with pressurised pivot irrigation systems for irrigating pasture were selected from dairy farms across the North and North-West of Tasmania (Table 1).

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Table 1. Pivot site locations

Site location	Soil characteristics
Cressy	Brown Dermosol - Cressy clay loam
Montana	Tenosol - Alluvial flood plain loam
South Riana	Brown Ferrosol - Yolla clay loam
Sisters Creek	Red Ferrosol
Rocky Cape	Hydrosol – flat drained swampland

Site characteristics

Electromagnetic conductivity (EM38) and elevation were mapped at each site. A minimum of three areas were selected under each pivot for detailed soil assessments. These areas were selected based on the EM38 spatial maps, elevation and site history. Soil pits were dug to a depth of 1.2 m and soil cores were collected from each soil horizon to determine bulk density, soil moisture properties and soil texture. Soil samples were also collected from each horizon for determining soil nutrient properties and particle size.

Sensor deployment and data logging

Sensors for measuring water and electrical energy use and soil moisture and temperature were installed at each site. Water flow was measured with ultrasonic sensors at three of the farms (South Riana, Sisters Creek and Rocky Cape). Existing flow meters were used at the Montana (ELSTER R2000) and Cressy sites (BERMAD Turbo-IR-A). Sentek drop and drill soil moisture probes were installed at Cressy, Montana and Rocky Cape and Aquacheck soil moisture probes were installed at Sisters Creek and South Riana. Each probe measured soil moisture at 10, 20, 30, 40, 50 and 60cm depths and soil temperature at 10, 30 and 60cm depths. Electrical energy meters were installed at all five sites (Schneider PM800 series) and this data was logged onto a Datataker logger (DT80). Data from the soil moisture sensors were recorded every 15 minutes at each probe with a WDC100 telemetry unit and this was then radioed to the Datataker logger located at the pump shed at each site. Data from the Datataker loggers was sent via an intercel Ultra SAM modem to a central server located at the University of Tasmania. A Davis Vantage Pro weather station was also set up on the Cressy farm to record rainfall, temperature, windspeed, relative humidity and solar radiation. This data was sent to the same central university server.

Data visualisation

On each of the farms, the Datataker loggers were set up to enable access to the data directly, via the Datataker DEX logger interface. The data on the central server was sent to a software interface (StruxureWare software (PME)) and various graphs were set up to visualise the water and energy use and soil moisture and temperature readings in near real time (30 minute delay).

Pasture growth measurements

Pasture growth rates were measured approximately every 7-10 days at each site during the 2015/16 irrigation season using a rising plate meter.

Decision making pathways

Two decision making pathways will be examined in this project. Pathway One will use a 'machine interface' (autonomous) decision making process on one of the dairy farms, while Pathway Two will use a 'human interface' for decision making on four of the dairy farms.

Machine interface

On one of the farms, a control engineering approach is being evaluated for automated irrigation management of dairy pastures. This control system consists of: (i) sensors to collect weather, soil and plant data (from camera images); (ii) a control strategy to process and analyse data to determine site-specific irrigation volume and day; and (iii) irrigation automation hardware to adjust irrigation application.

Two control strategies will be used: sensor-based control (SBC) that applies soil-water and/or nitrogen deficit when below a user-specified threshold; and Model Predictive Control (MPC) that uses a calibrated crop model to determine the optimal irrigation and/or fertiliser volume and timing (McCarthy et al. 2014a, 2014b). Simulation in the software 'VARIwise' and field studies have shown increased productivity of approximately 10% using MPC, where soil and plant data are available to calibrate the model and ensure that the model reflects field conditions (McCarthy et al. 2014, McCarthy et al. 2010).

Measured pasture growth data is regularly used to adjust pasture crop model parameters to minimise the difference between current modelled and measured data in the MPC strategy. In this way predictions of pasture growth are continuously improved.

For dairy pasture, these measurements include height and biomass. These measurements are typically labour-intensive to collect; hence automated camera and image analysis systems have been developed and installed along the irrigation machine. Smartphones were positioned along the irrigation machine with an app installed to collect top view images of the crop and GPS location every five minutes. These measurements have been ground truthed against high spatial resolution pasture height measurements that are collected weekly using an on-the-go 'C-Dax' quad-bike unit (Fig. 1).

(a) (b)

Figure 1. (a) Smartphone units installed on an irrigation machine at the centre of three spans at TIA Dairy Research Farm; and (b) sample image from machine

The plant cameras will be evaluated over the 2016/17 dairy season for accuracy of height and dry matter estimation and ability to calibrate the 'AgPasture' model in APSIM for the MPC strategy. The automated SBC and MPC irrigation control systems will be evaluated at the sites in the 2017/18 dairy season.

Human interface

On four of the farms, a human interface decision making process based on results from the installed sensors and system analysis will inform potential system modifications. System performance will be determined without consultation in the initial year of the project. A consultative engagement process between key stakeholders will result in knowledge brokering and agreed practice change. These changes will be evaluated in 2016/17, re-evaluated and refined and reassessed in 2017/18.

Broader industry engagement

Broader dairy farmer engagement and extension will be conducted via workshops and field days on selected farms. These meetings will discuss changes in irrigation scheduling, system design modification and water, and energy saving associated with both the autonomous focus farm and the four other dairy farms. This extension and communication package will be repeated in each irrigation season.

Preliminary Results and discussion

These results focus on examples of preliminary outcomes for the first 3 aims of the project; namely benchmarking of irrigation system performance, adoption of practices for minimising waterlogging and nutrient losses and the development of an autonomous irrigation control system.

Benchmarking of irrigation system performance

Energy used for pumping the irrigation water varied significantly between sites, ranging from 113 kW.h/ML at the Rocky Cape site to 787 kW.h/ML for the Sisters Creek site (Table 2).

Table 2 Energy use and estimated energy cost for irrigation at the five pivot sites

Pivot Site	Flow m^3/hr	Pump Size	Motor size (kW)	kW.h/ML	$/kW.hr	$/ML
Rocky Cape	232	150×125-315	30	113	0.23	$26.08
Montana	225	150×125-315	37	157	0.23	$36.16
Cressy	316	150×125-250	75	220	0.23	$50.65
South Riana	163	100×75-315	45	304	0.23	$70.00
Sisters Creek	108	100×65-315	75	787	0.23	$181.05

There were clear issues with the suitability of the pumping equipment at the Sisters Creek site with a system designed for use with high pressure travelling irrigators being used for a low pressure pivot irrigation system through the addition of a pressure reducer. Preliminary pump test results from the Sisters Creek site indicate that pumping costs can be reduced to between 25 and 33% of current levels with some reasonably simple changes to the existing equipment. Appropriate capital investment in sites like this could achieve a payback on this investment within 2 years.

Adoption of practices for minimising waterlogging

At the Cressy site, monitoring revealed issues with achieving uniform soil moisture across the site. An assessment of the site prior to the start of the irrigation season using soil cores and EM38 mapping enabled identification of different zones to monitor the effect of irrigation on soil moisture content. Soil moisture probes were installed in the three main EM38 zones (Fig. 2).

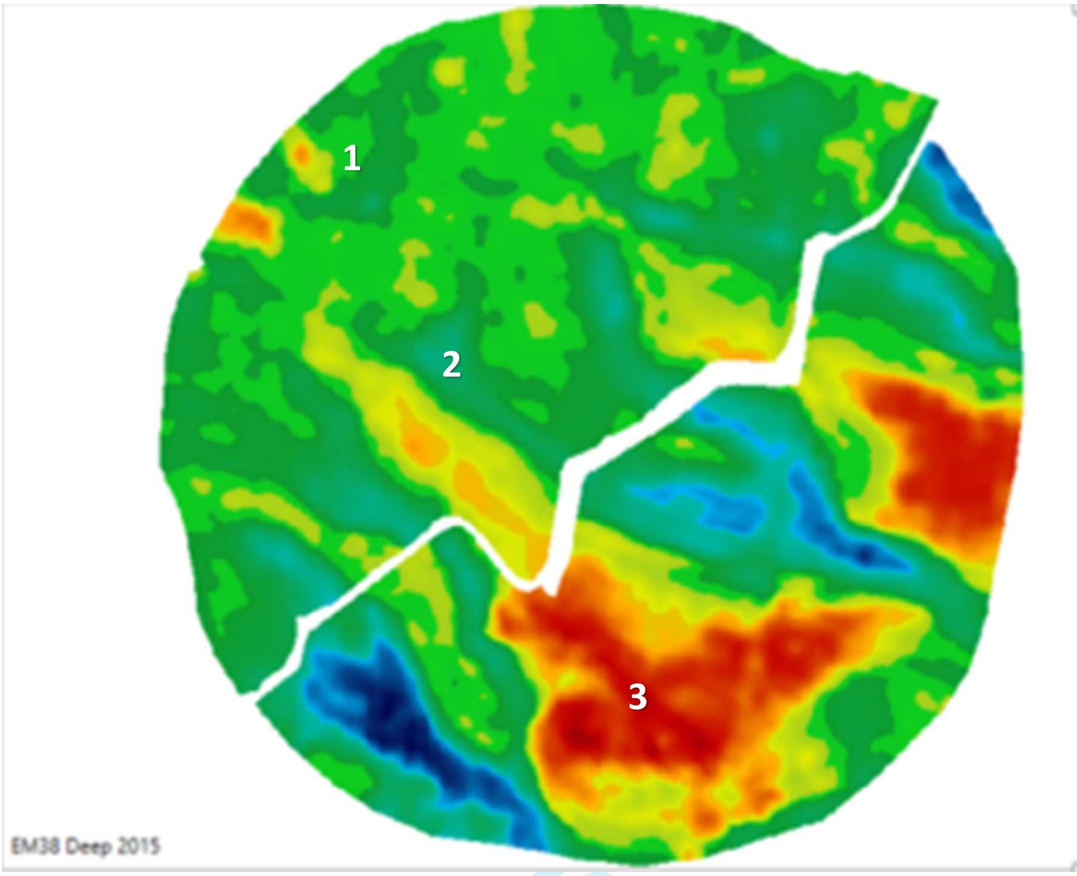

Figure 2. Location of soil probes in different EM38 zones at the Cressy pivot site. The position of numbers indicated the position of specific probes.

Probe 1 was located on an elevated section of the site that had a medium EM38 reading relative to the other probe locations. Moisture levels at this probe fluctuated significantly during summer and early autumn (Fig. 3) between irrigation/rain events. In contrast, probe 2, which was located in wetter ephemeral stream lines, reported moisture levels that were consistently high (Fig.4). Probe 3 at Cressy was located on a slightly elevated ridge on the lowest half of the pivot area.

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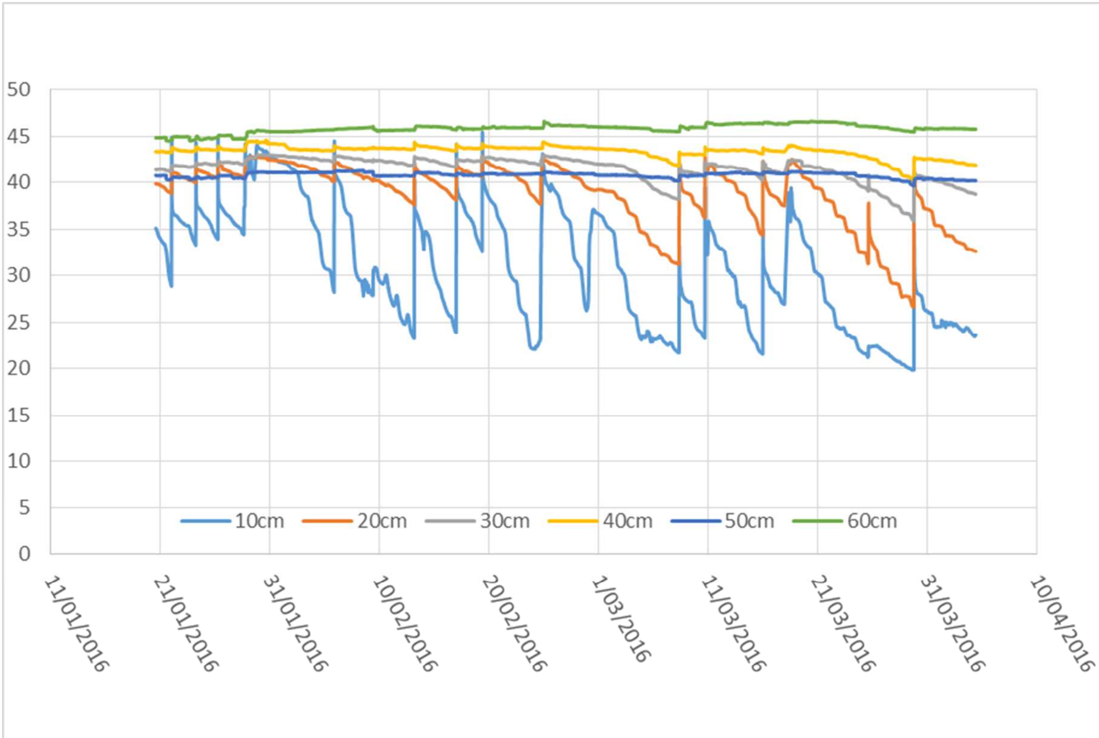


Figure 3. Capacitance probe moisture content (%) at 6 depths for probe 1 (dry elevated position) at the Cressy site.

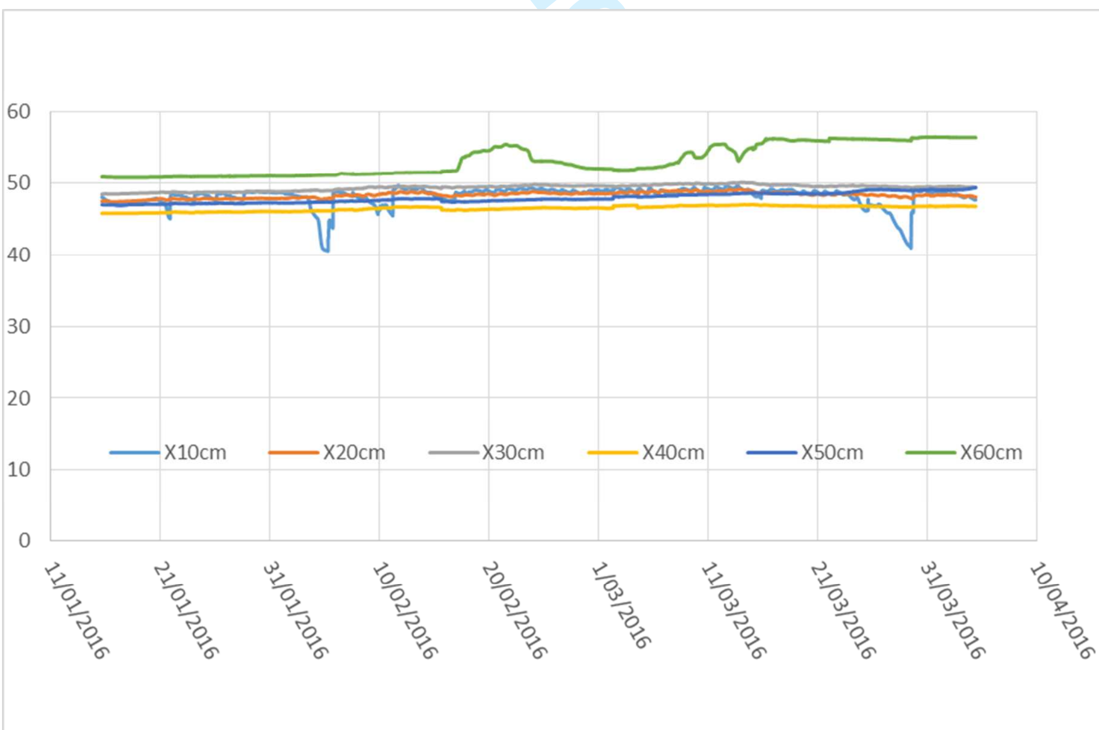


Figure 4. Capacitance probe moisture content (%) at six depths for probe 2 (moist gully) at the Cressy site.

The results of the soil moisture monitoring indicated that irrigation was inadequate for a significant area of the pivot (approximately 60%). During the summer months average pasture growth rates achieved for this 113ha pivot site were close to 40 kg DM/ha/d. This was about 20kg DM/ha/d lower than the average growth rate for the Montana site during the same period. This difference represents a lost opportunity for pasture production, equivalent to approximately 180t of pasture DM over a 3 month period. Under watering appeared to be the main cause for this poor performance, but any increase in the frequency or quantity of water applied was considered difficult due to the risk of trafficability with the pivot through the low lying streamlines.

Based on these initial soil moisture observations and pasture growth rate measurements, the farmer has determined that investment in variable rate irrigation technology is warranted. Using variable rate technology the dry areas have increased irrigation inputs and the wet areas can have reduced or no inputs. This should lead to increased pasture growth rates without the issue of pivot traffic on wet soils. The use of the variable rate irrigation technology for reducing waterlogging issues on this site and potentially increasing pasture growth rates will be investigated during the 2016/17 season.

Development of an autonomous irrigation control system

Using image analysis for estimating pasture biomass

Images captured within two days of C-DAX data collection and that were within 2 metres of the GPS location of the C-Dax data were analysed and compared with the C-Dax height measurement. Figure 5 shows the results for 12 images and the corresponding height from the C-Dax. Figure 6 shows the correlation between a pasture height map from an infield pasture height sensor and image analysis.

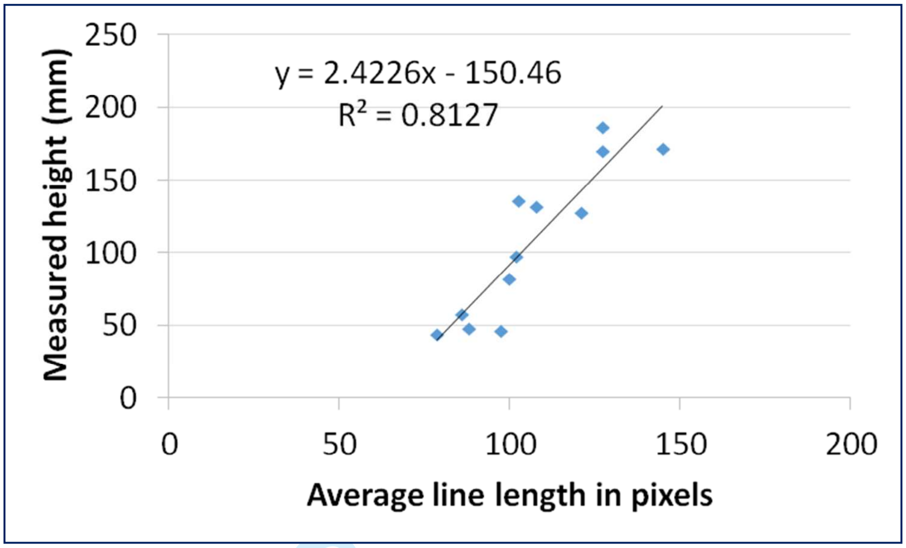
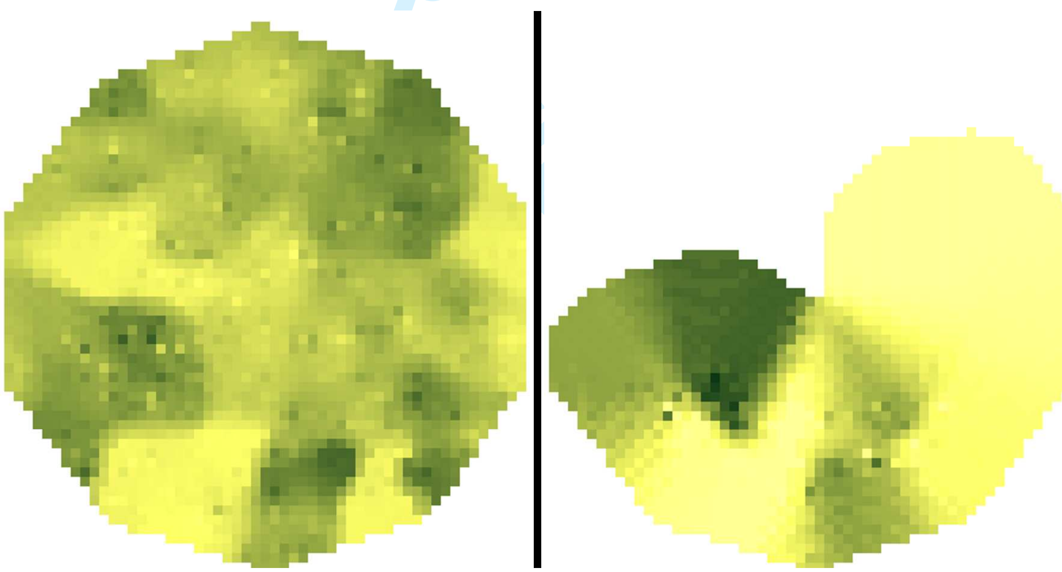


Figure 5. Performance of the height detection algorithm where the average pixel length of leaves was correlated with the measured height of the pasture using a C-DAX.



(a) (b)

Figure 6. Comparison of pasture data collected on 29 December 2015 from: (a) C-dax pasture height sensor; and (b) irrigation machine smartphones. White areas indicate locations where no data was collected from the quad bike or the irrigation machine did not pass that area of the field.

Further development of the image analysis for pasture biomass assessment will occur at the Montana site in 2016/17. This will be followed by full testing of the autonomous control system in the 2017/18 season at this site.

Conclusions

Data collected during the 2015/16 irrigation season has been used to inform exploration of issues with the irrigation systems on the five farms and has enabled an objective assessment of the factors that should be modified and tested for improved efficiency of water use and pasture productivity. During the second irrigation season, modifications will be assessed and regular communication and updates from the monitored data will be used to further improve decision making processes for each of the sites. At the machine interface site, there will be a focus on setting up the enabling technology for automation and refining of the biomass estimation methodology via image analysis.

Field days will be organised prior to the start of the 2016/17 irrigation season to engage other local farmers and service providers on the findings and increase their interest in the issues identified and modifications being tested at these sites

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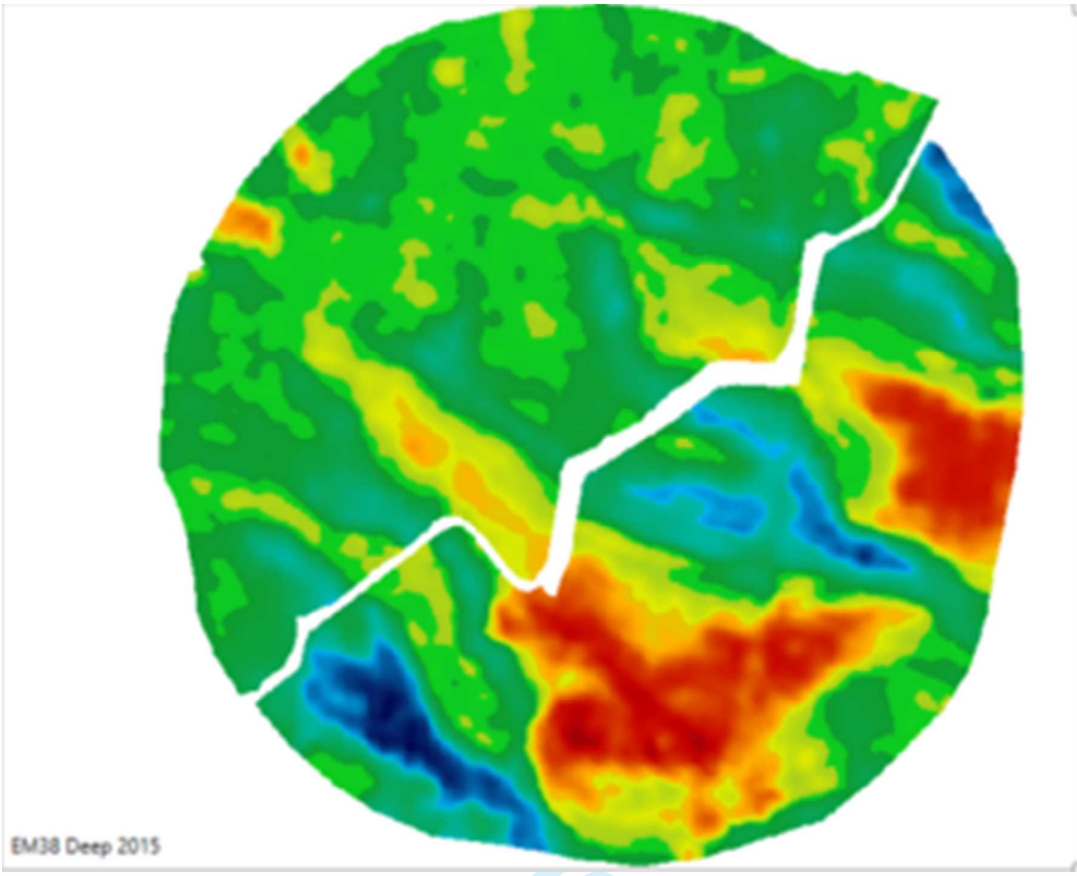

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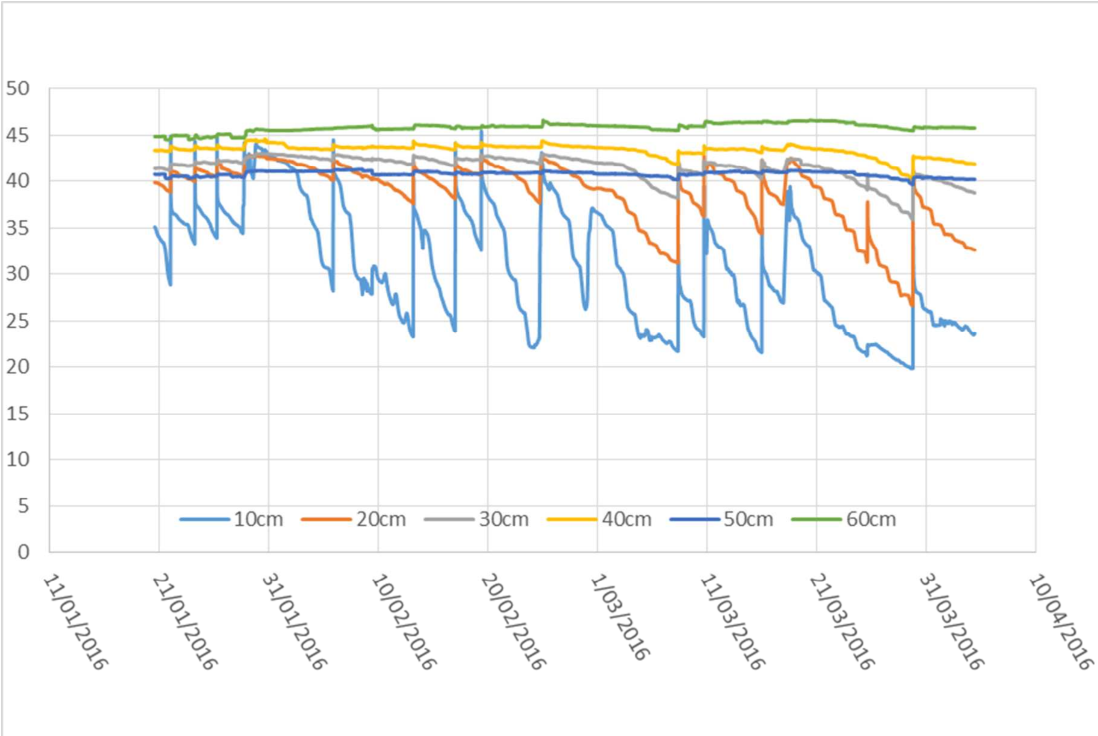

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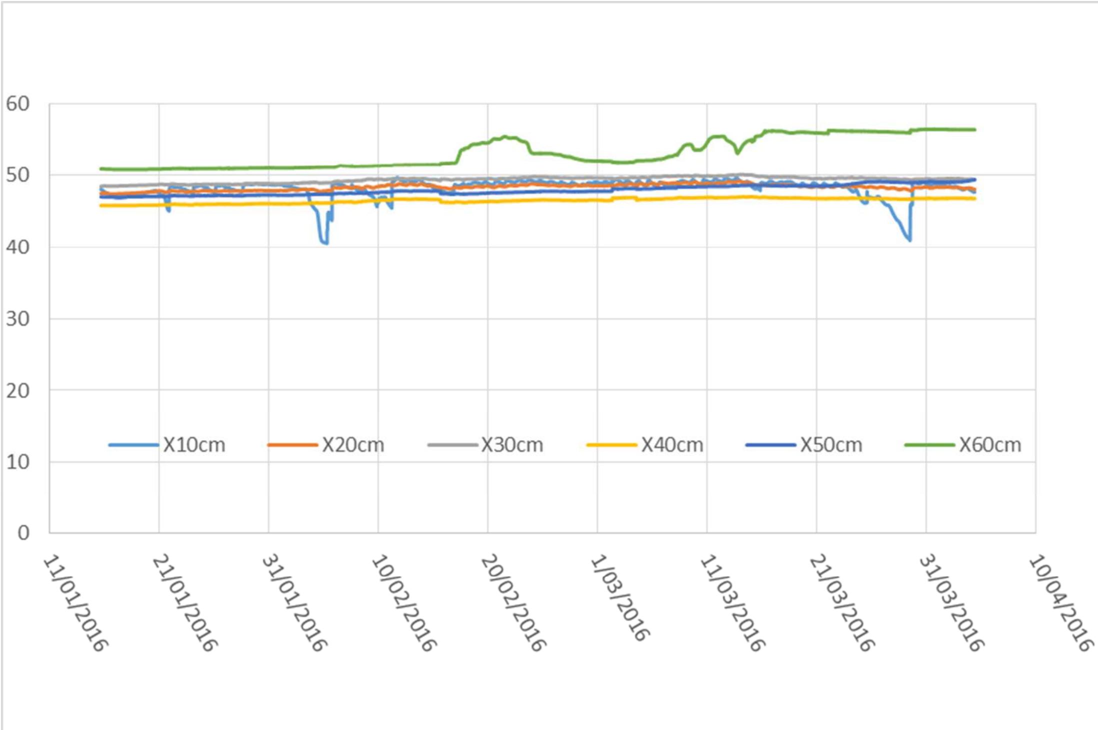
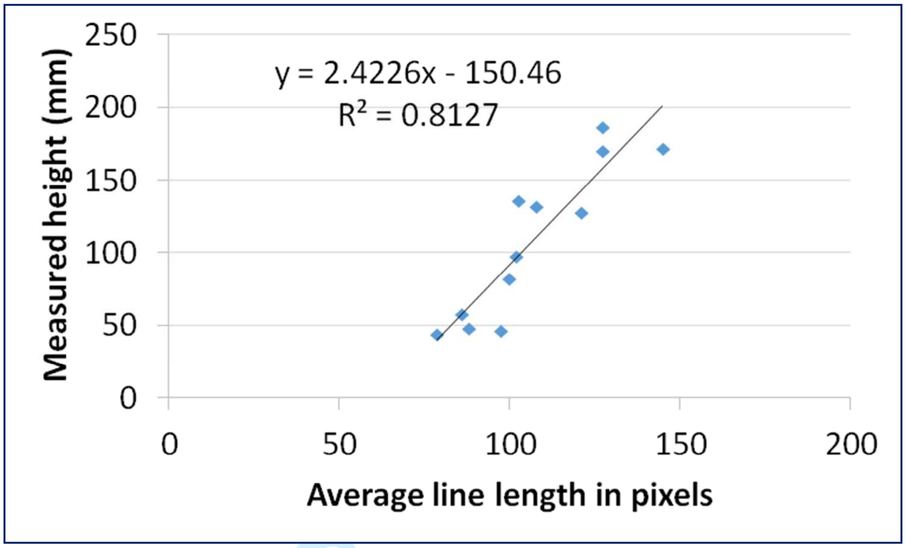


Figure 4. Capacitance probe moisture content (%) at six depths for probe 2 (moist gully) at the Cressy site.



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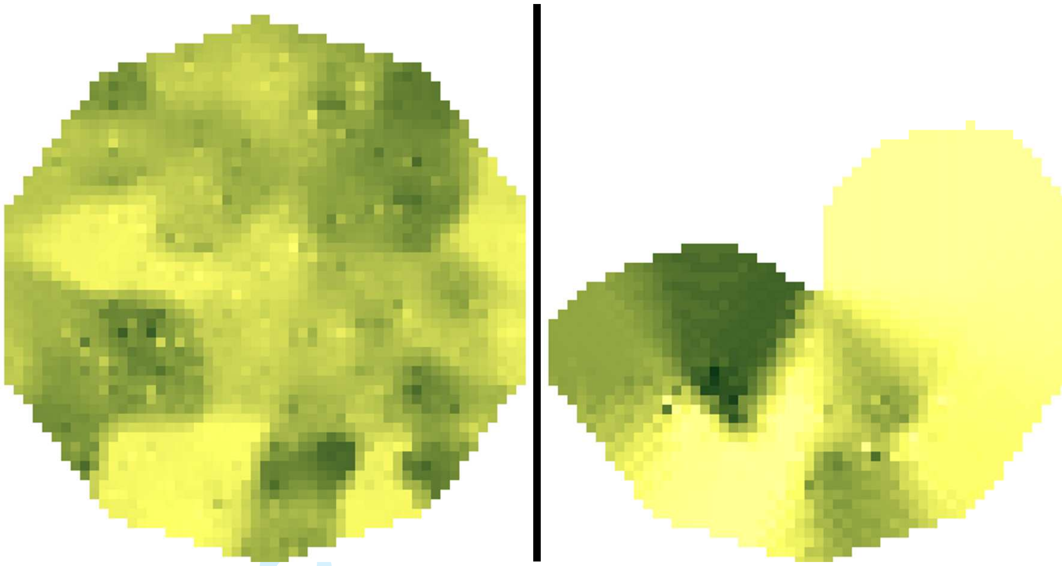

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