



Rural Research and
Development for Profit
Keeping Australian farmers
at the cutting edge



Australian Government
Department of Agriculture
and Water Resources



Australian Government
Cotton Research and
Development Corporation



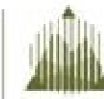
Dairy
Australia

Automated camera-based crop monitoring and site-specific irrigation control systems for cotton, horticulture and dairy pasture

Dr Alison McCarthy

National Centre for Engineering in Agriculture
Institute for Agriculture and the Environment
University of Southern Queensland

NCEA's automation research

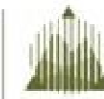


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- Machine vision, automation, robotics
- Low cost machine guidance
- Precision monitoring tools



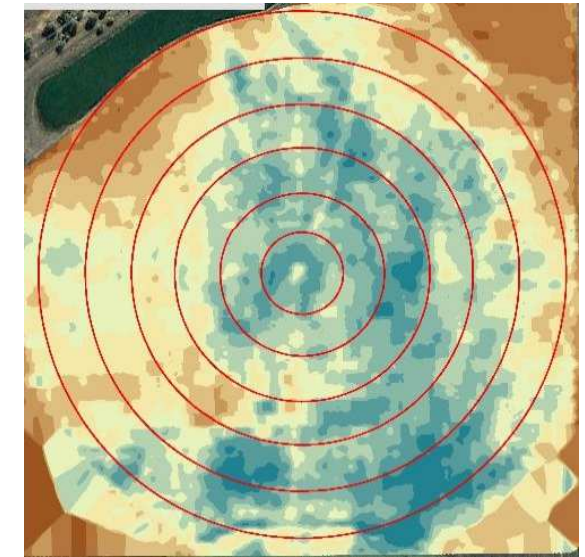
Variable-rate technology for overhead and surface irrigation



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EM

- CPLM VRI is historical map based
- Surface irrigation automation hardware is time based
- Developing automated control strategies for timing and volume



Pulsing solenoids on VRI



Source: Valley

Rubicon automation hardware

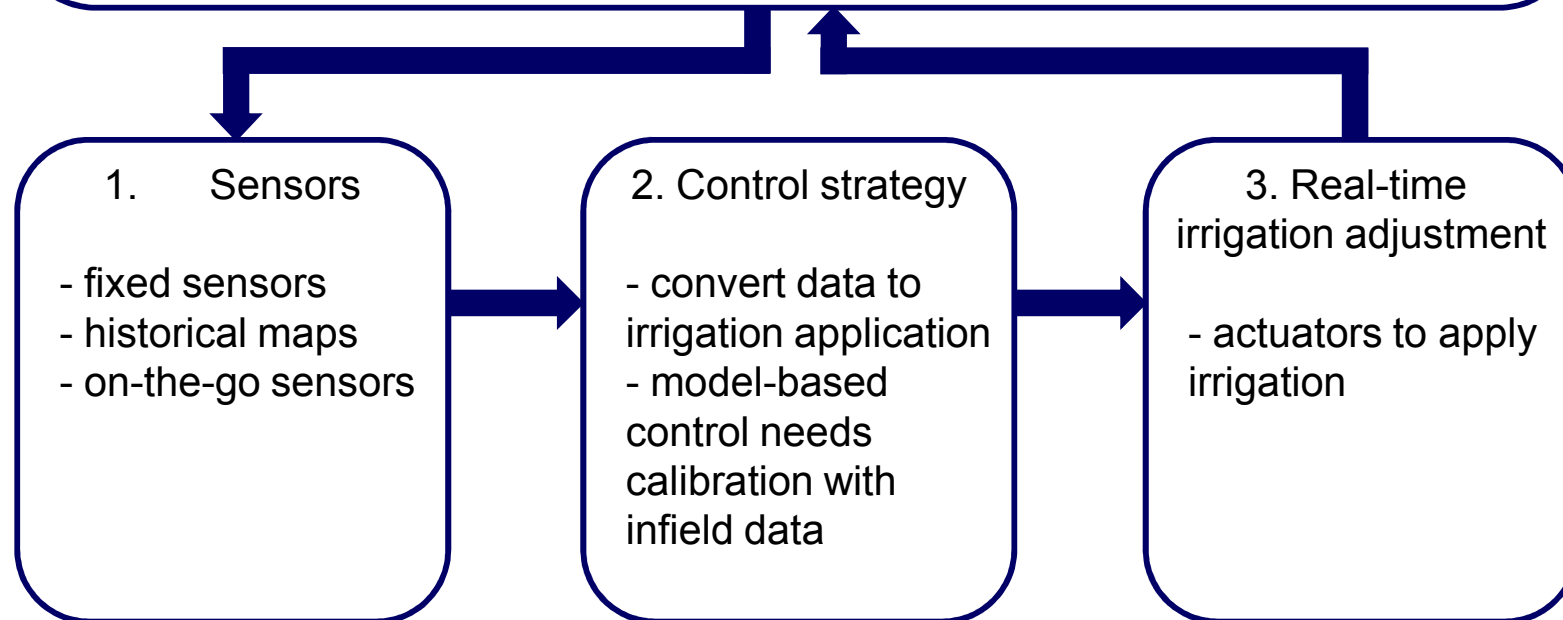


Site-specific irrigation control system

Surface irrigation system



Overhead irrigation system



Irrigation automation projects

- CRDC research project:
 - Evaluate adaptive control systems for surface irrigated and fertigated cotton
- QLD Government Accelerate Fellowship:
 - Evaluate automated site-specific irrigation for beans and carrots in SE QLD and NZ
- Rural R&D Smarter Irrigation for Profit:
 - Demonstrate automated irrigation control system with commercial VRI for cotton, dairy, sugarcane
 - Scoping out off-the-shelf technology for data processing and hardware update

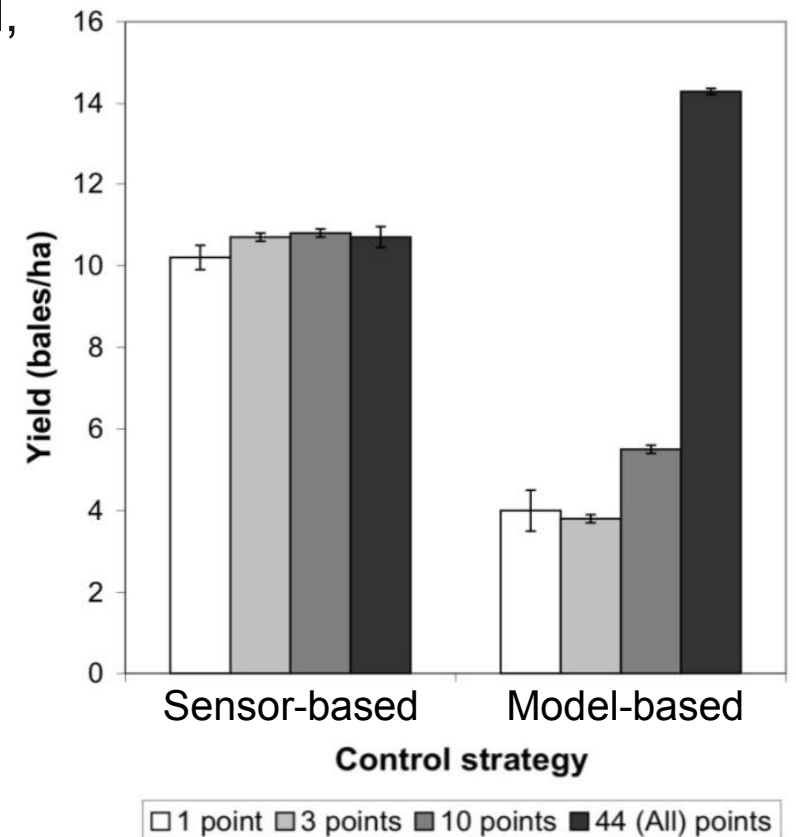
Irrigation control strategies

■ Sensor-based control (ILC):

- Soil moisture status estimation using soil, temperature and/or reflectance sensors

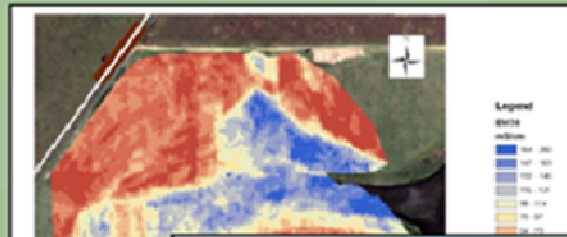
■ Model-based control (MPC) using APSIM or AI model:

- A calibrated crop model simulates and *predicts* the next required irrigation, i.e. volumes and timings
 - according to evolving crop/soil/weather input
 - separately for all cells/zones
 - can *choose* alternative end-of-season predicted targets
- Sensitivity analyses for data requirements
- Potentially higher yields than sensor-based control

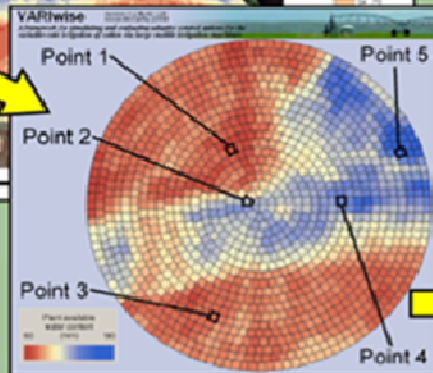


Simulation of sensor-based control

1. EM38 map imported into VARIwise



2. Plant available water content map



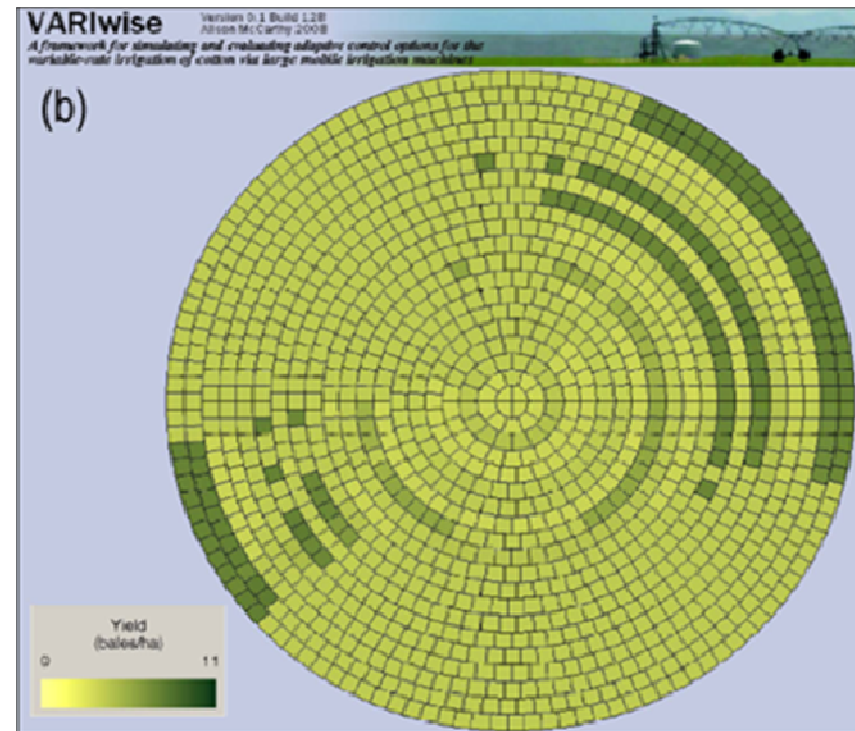
3. Centre pivot uniformity can be imported

4. Control options

A. Fixed irrigation schedule
Irrigation is applied according to user-specified dates and amounts

B. Soil moisture deficit-triggered irrigation

C. Adaptive control

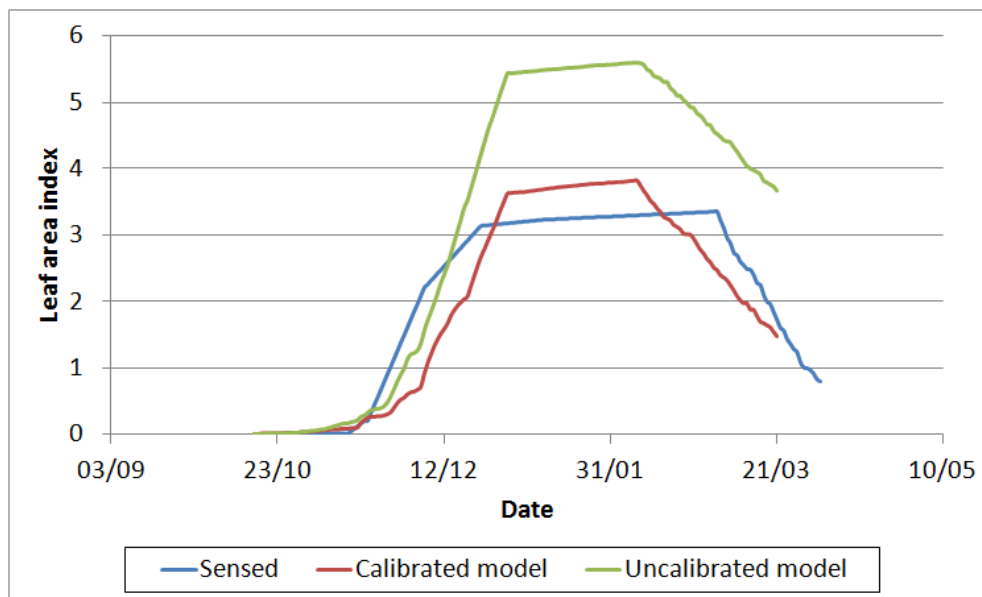


Sensor location	Variability in machine uniformity	Yield (bales/ha)	Irrigation water use efficiency (bales/ML)
Point 1	Low	7.0	0.7
	High	7.0	1.0
Point 2	Low	7.1	0.7
	High	7.0	1.0
Point 3	Low	7.1	0.8
	High	4.6	0.4
Point 4	Low	6.8	0.7
	High	7.0	1.0
Point 5	Low	7.4	0.9
	High	7.0	0.9

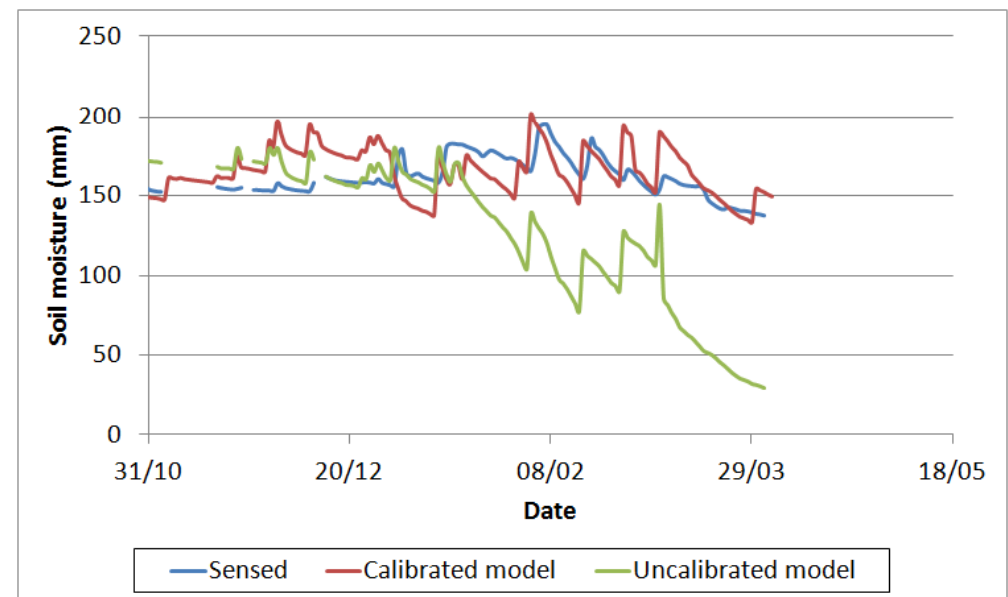
Model calibration

- Model is calibrated in each cell
- Sensitivity analysis to determine input parameters to adjust
- Automatically adjust input parameters until output reflects measurements

Plant growth calibration



Soil moisture calibration



Data pre-processing

- Convert all data layers to spatial grid
- Kriging to assign value to each cell within field
- Robustness evaluation being conducted on number and location of sensors and cameras required

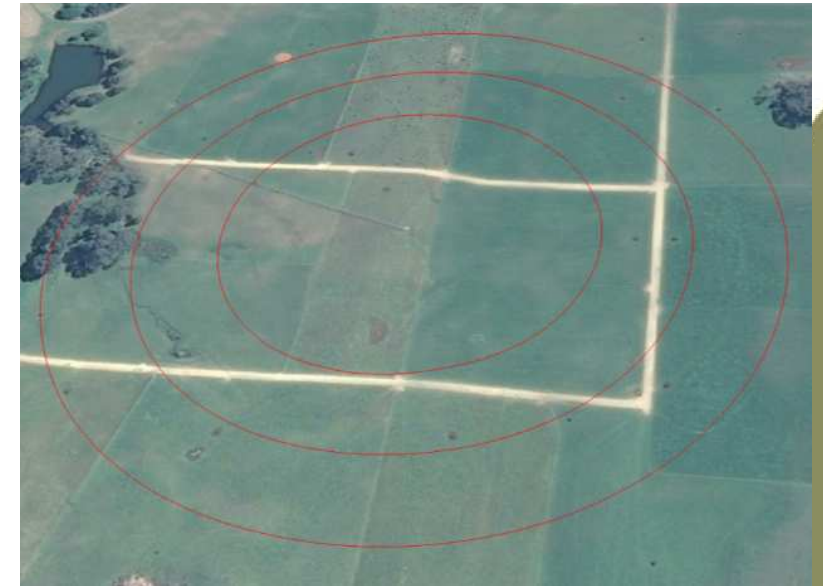
Fixed sensor



Ground vehicle



Cameras on pivot



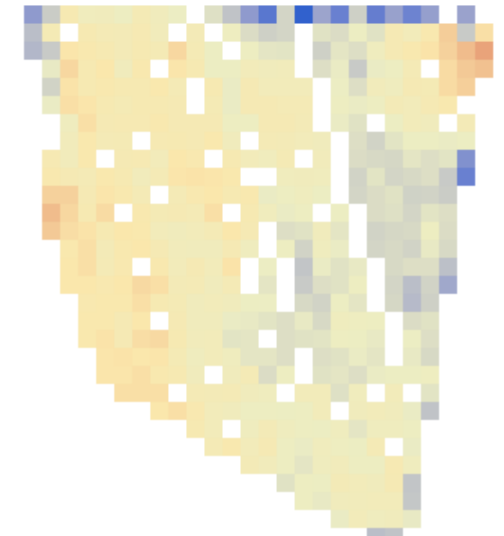
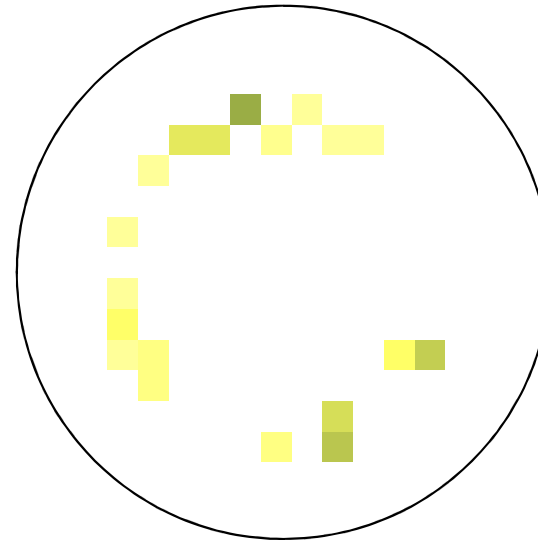
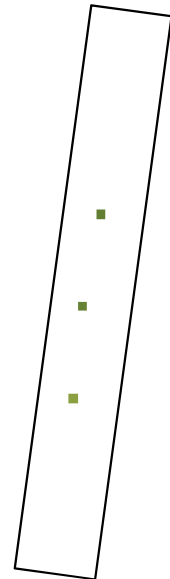
Gridded data

Single points

On-the-go

Mapped

Before
interpolation



After
interpolation

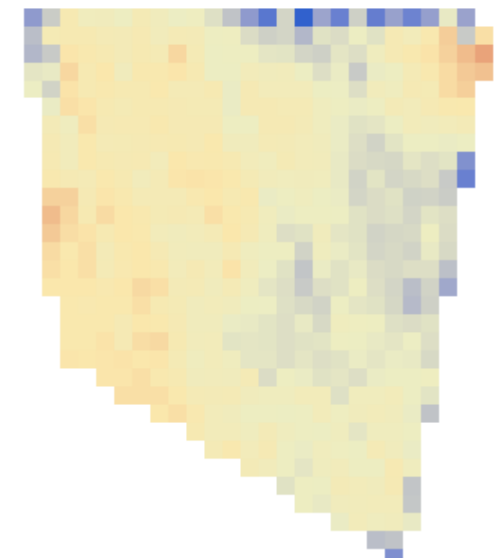
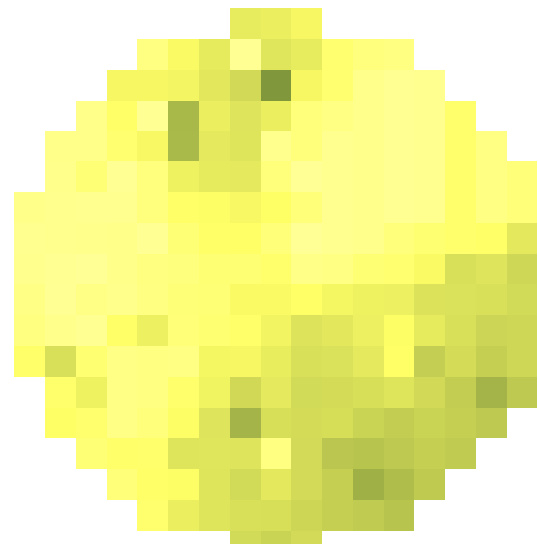


Image data input

- Use low-cost cameras to estimate cover and height
- Multiple cameras on irrigation machine and ground vehicles

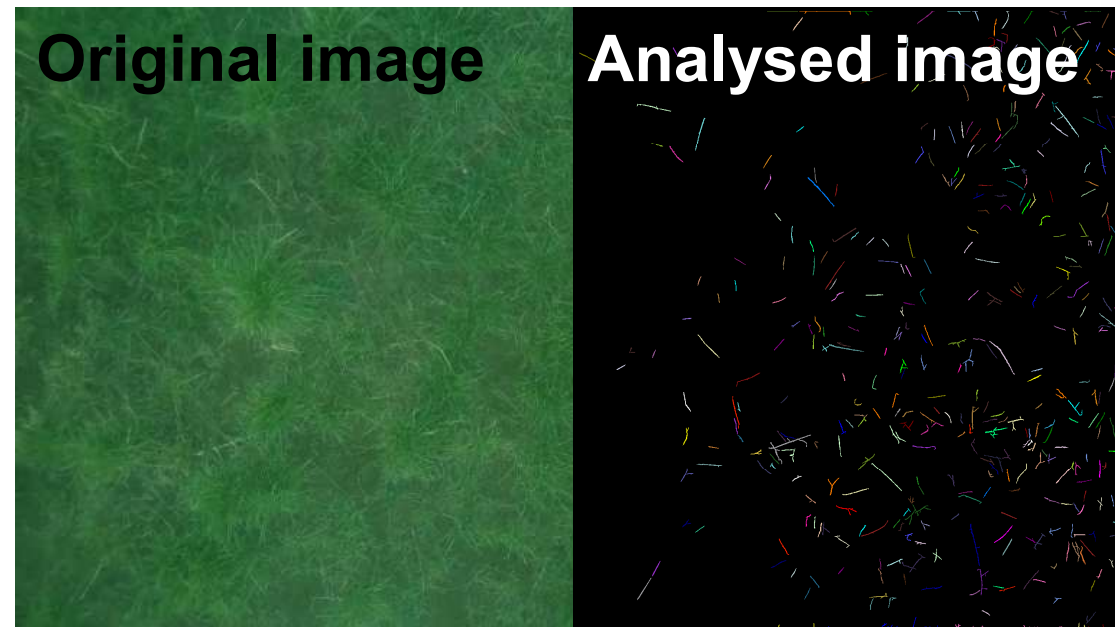
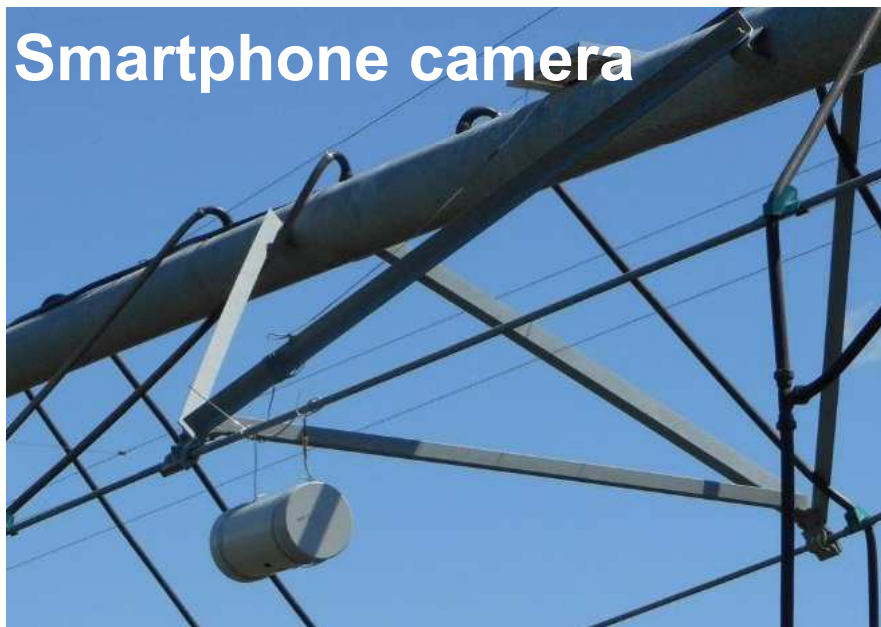
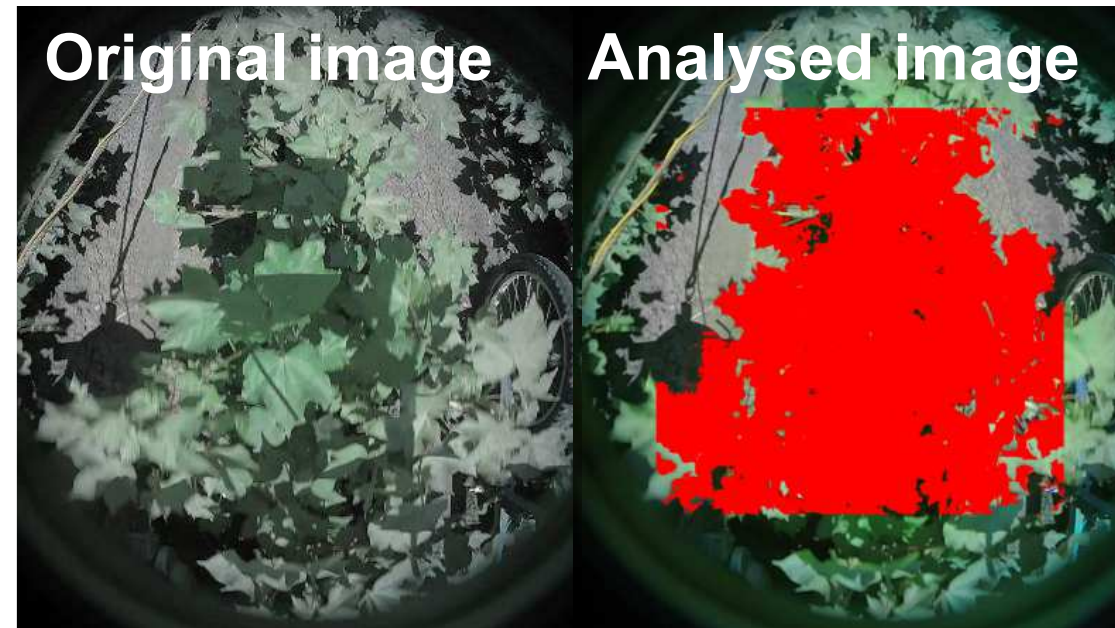
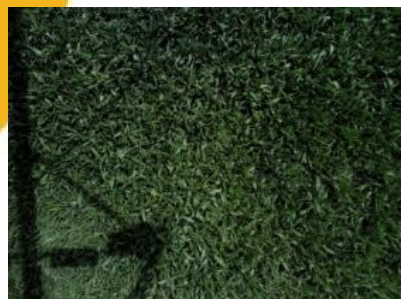
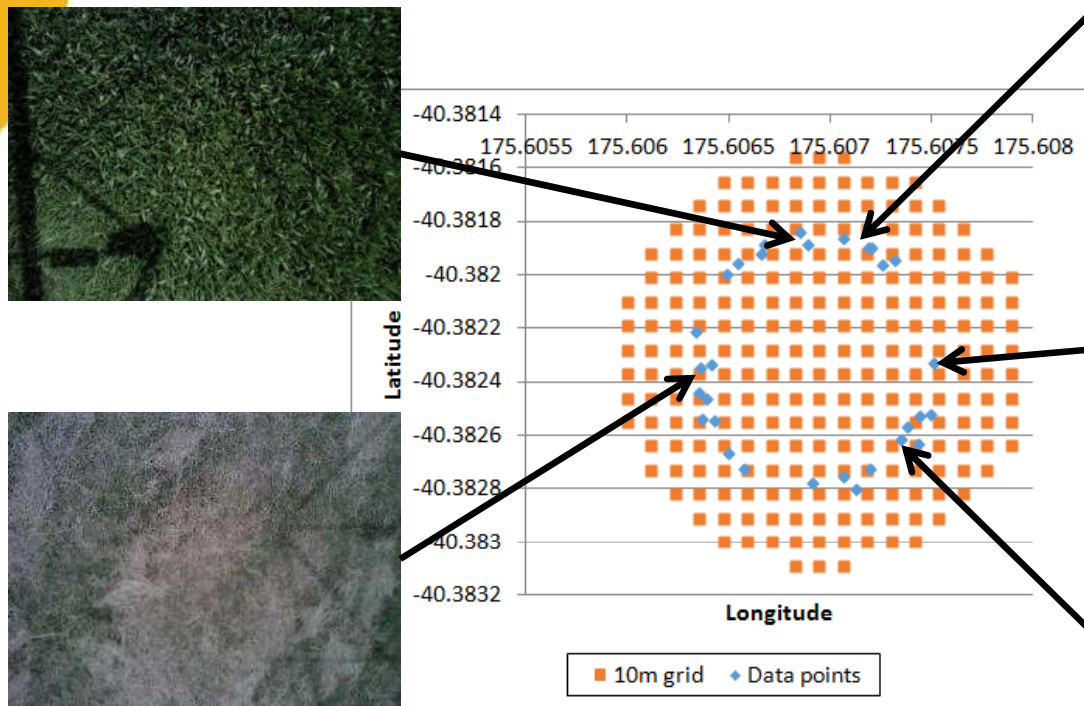


Image data pre-processing

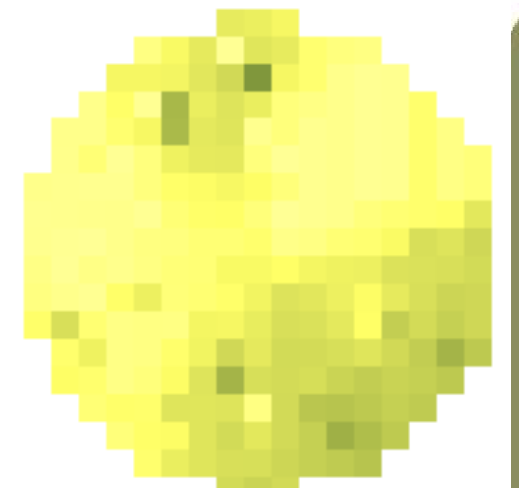
1. Collect images and location



2. Analyse images



3. Interpolate map



Upload map to VRI system

1. Generate shape file for VRI map
 2. Manually input shape file into VRI software
 3. Start irrigation
- VRI testing commenced in horticulture and cotton

Valley VRI map upload:

The screenshot displays the VRI software interface. On the left, a 'Zones table' lists various irrigation zones with columns for Start Angle, Stop Angle, Start Radius, Stop Radius, Area (ha), Application (mm), Speed (%), Lock, and VRI Determinance. The central part of the interface shows a circular VRI map with a color-coded overlay representing different irrigation zones. On the right, a control panel for the '[002] Big Pivot' is visible, showing the VRI Program settings, including the Mode (Zone), Zone Prescription, and VRI status (Off). The control panel also includes a 'Notes' section with details about the pivot's location and irrigation parameters.

Start Angle	Stop Angle	Start Radius	Stop Radius	Area (ha)	Application (mm)	Speed (%)	Lock	VRI Determinance
318	320	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
318	320	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
320	322	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
320	322	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
322	324	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
322	324	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
324	326	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
324	326	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
326	328	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
326	328	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
328	330	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
328	330	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
330	332	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
330	332	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
332	334	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
332	334	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
334	336	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
334	336	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
336	338	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
336	338	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
338	340	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
338	340	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
340	342	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
340	342	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
342	344	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
342	344	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
344	346	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
344	346	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
346	348	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
346	348	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
348	350	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
348	350	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
350	352	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
350	352	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
352	354	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
352	354	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
354	356	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
354	356	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
356	358	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
356	358	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil
358	360	122.7	170.2	0.04	50.8	32.80		EM38 Subsoil
358	360	141.3	162.7	0.08	50.8	33.83		EM38 Subsoil

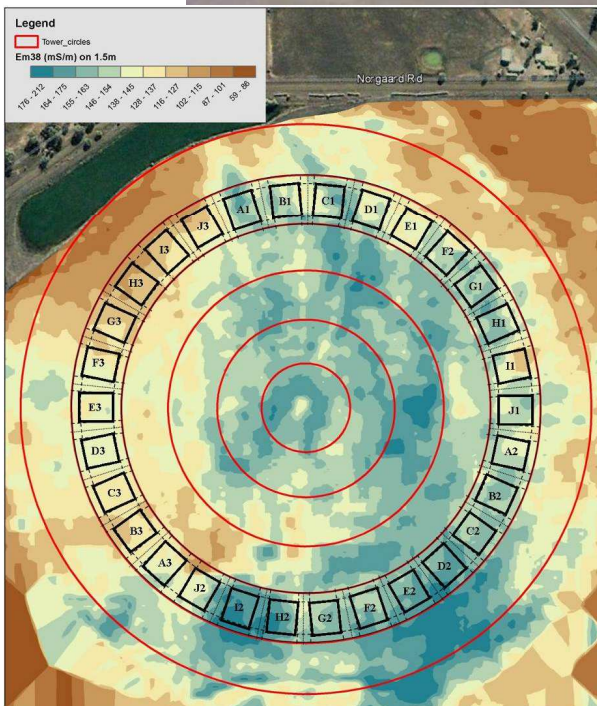
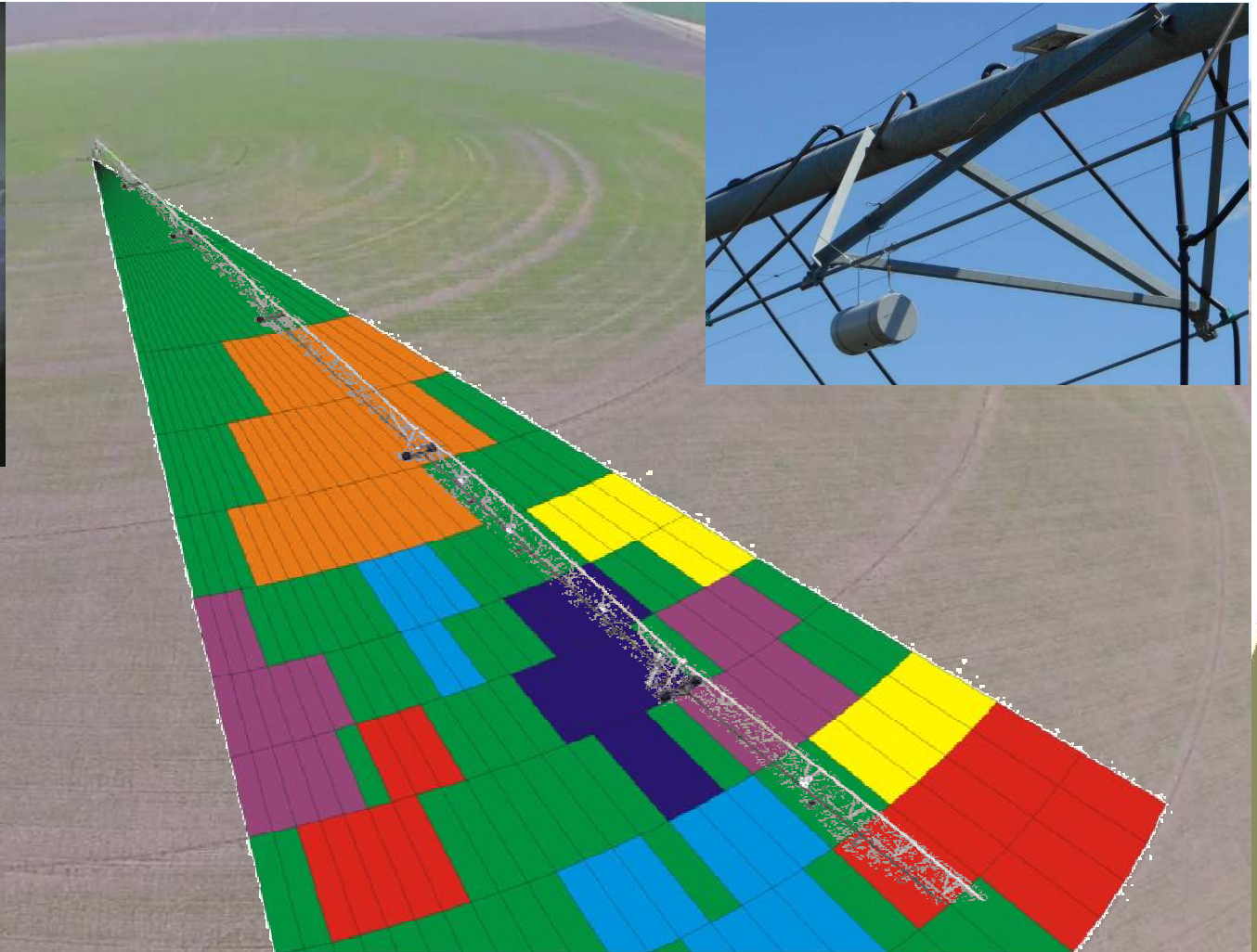
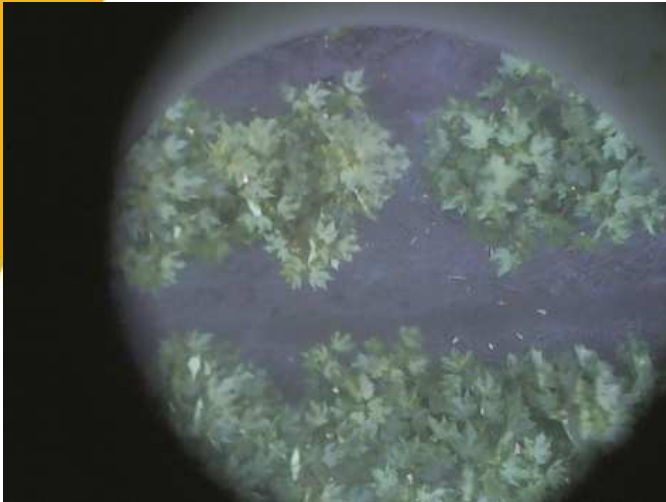
Summary:
Total Area: 22.61 ha Total Base Water: 1.61 (602mm/ha) Total VRI Water: 1.61 (602mm/ha) Total Time: 0d 16h 5min

Control system implementation on centre pivot



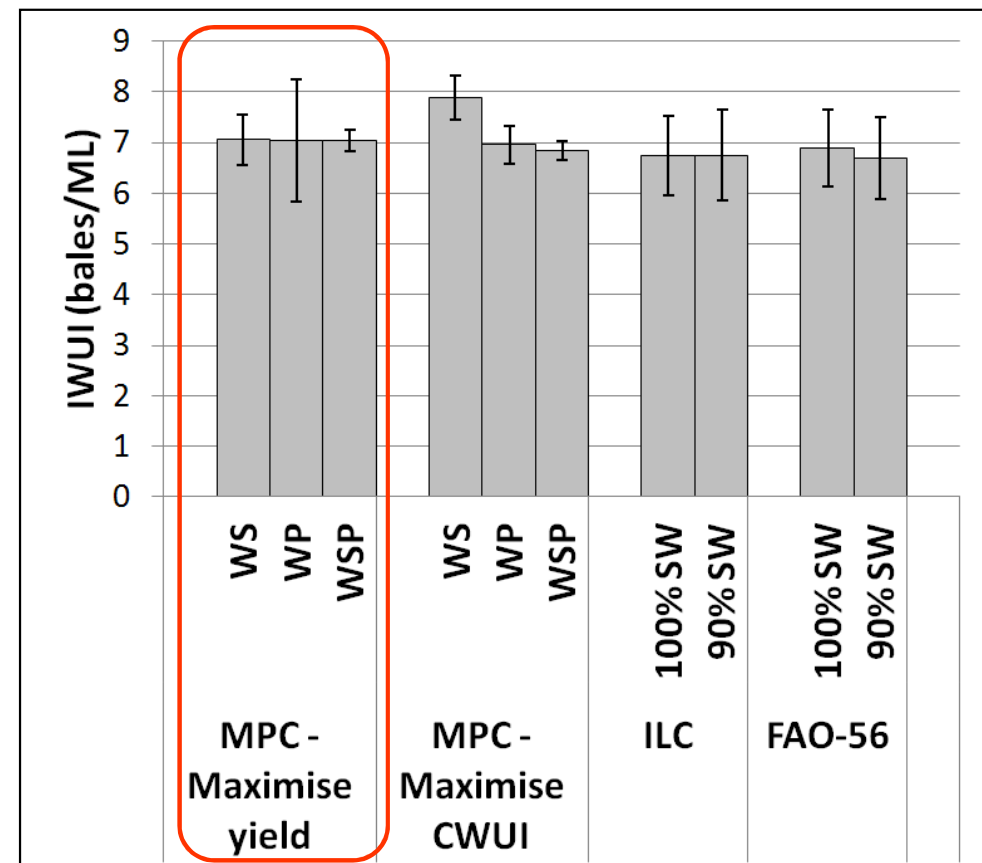
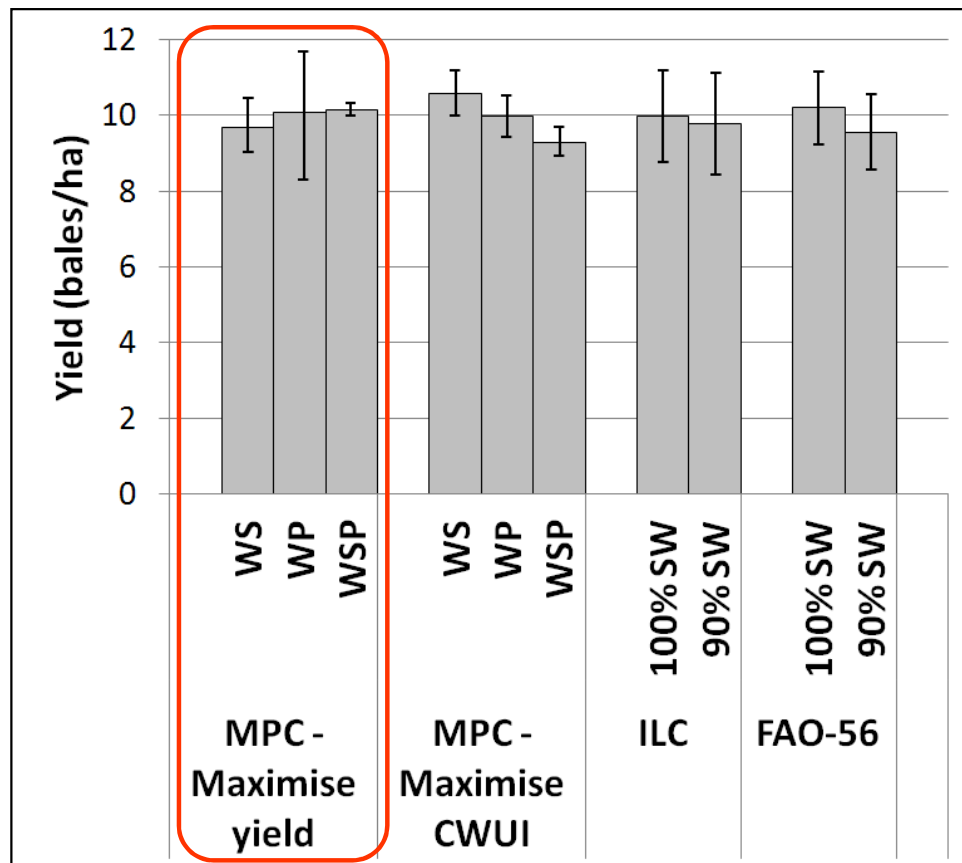
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Real-time camera-based plant sensing to update irrigation:



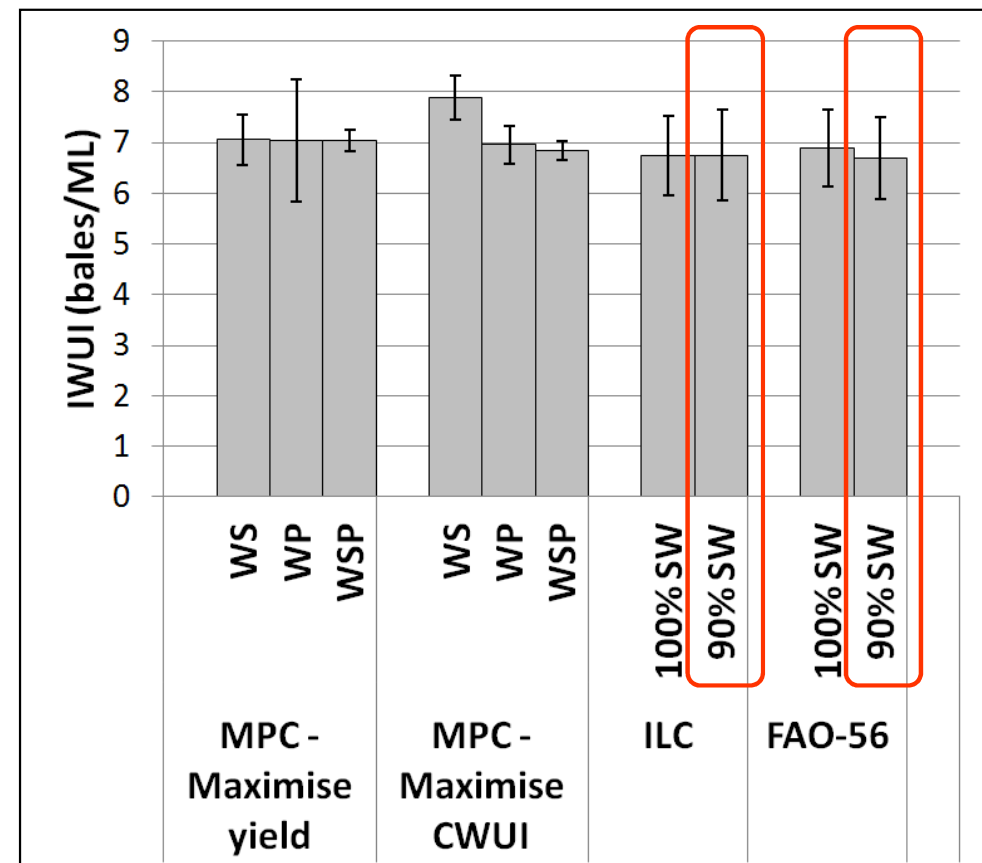
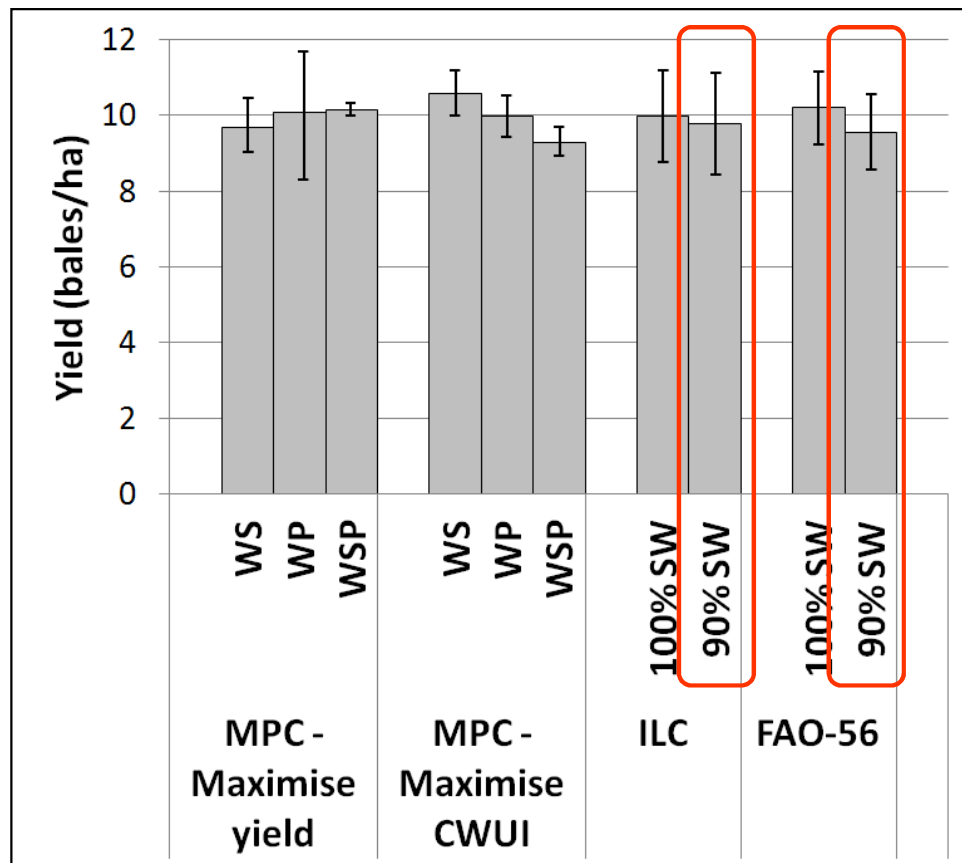
Centre pivot trial – MPC yield

- Plant data input led to higher yield, no change in IWUI
- Plant data input increased yield for MPC maximising yield



Centre pivot trial – sensors

- Higher yield and IWUI for ILC then FAO-56
- ILC better for targeting deficit irrigation than FAO-56



Control system implementation for surface irrigation



Crop growth and fruiting sensing using cameras

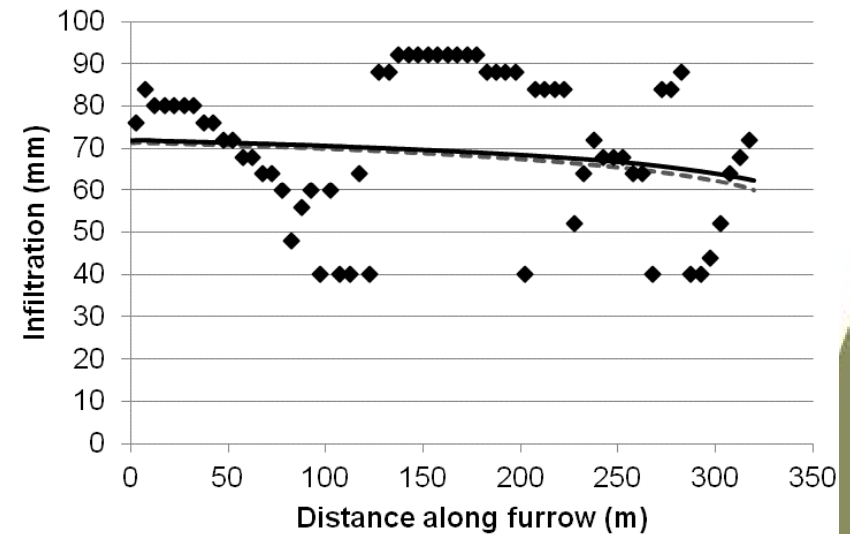


Soil-water, weather



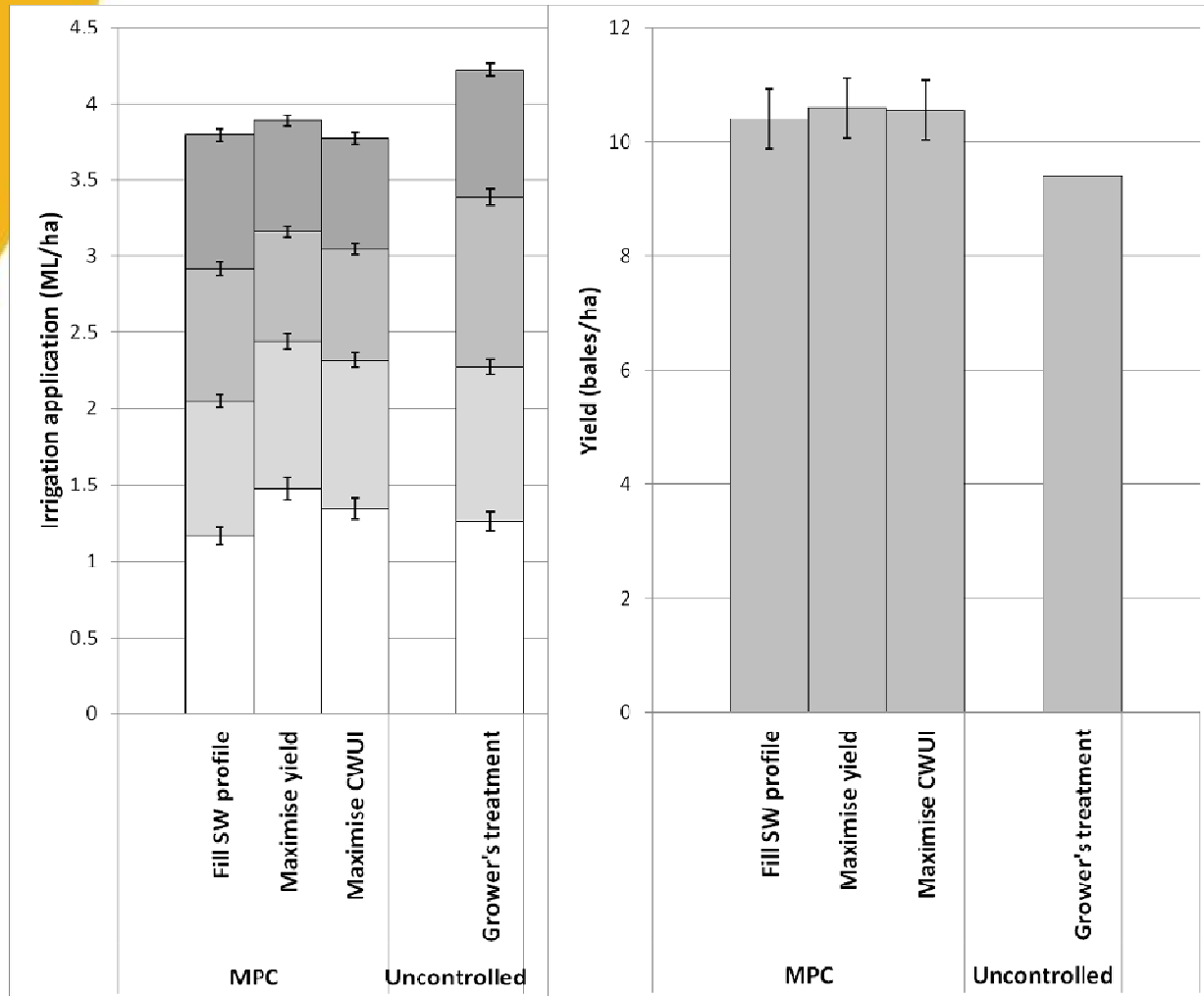
Control strategy determines irrigation along furrows

Determine flow rate and cut-off time

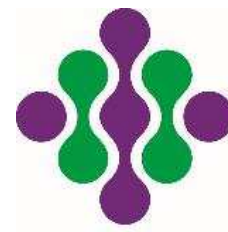


----- Predicted ◆ Optimal — Fitted

Surface irrigation trial



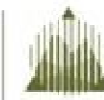
Automated irrigation for dairy pastures



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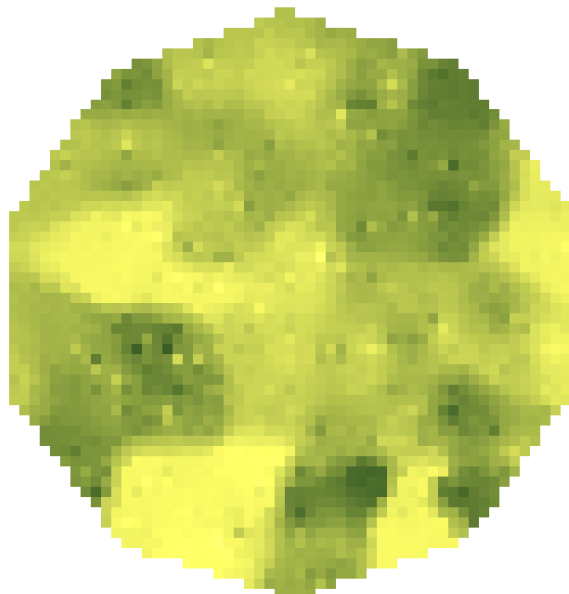


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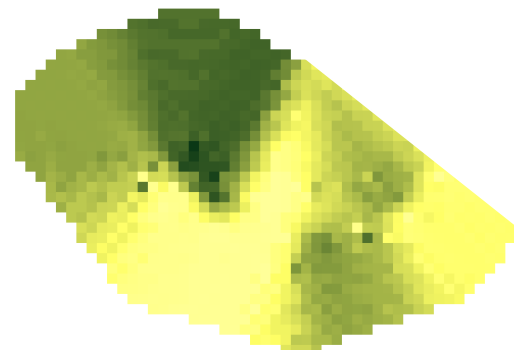
- Pasture height used for grazing, irrigation
- Image analysis for leaf length and cover

Height from quad bike sensor



Canopy cover from cameras

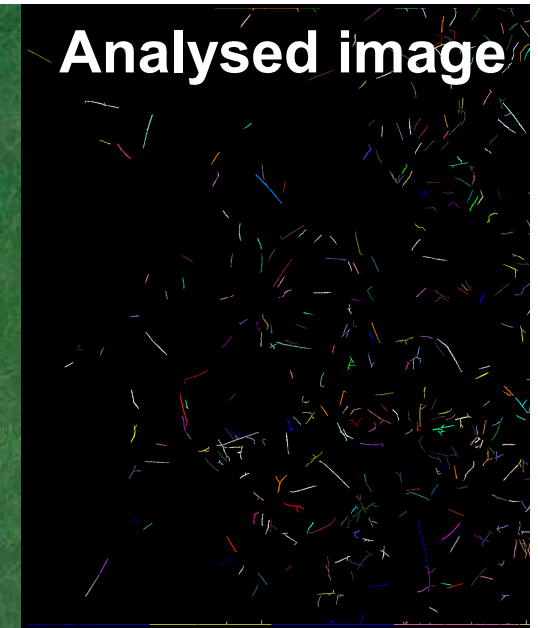
0 Height (mm) 250



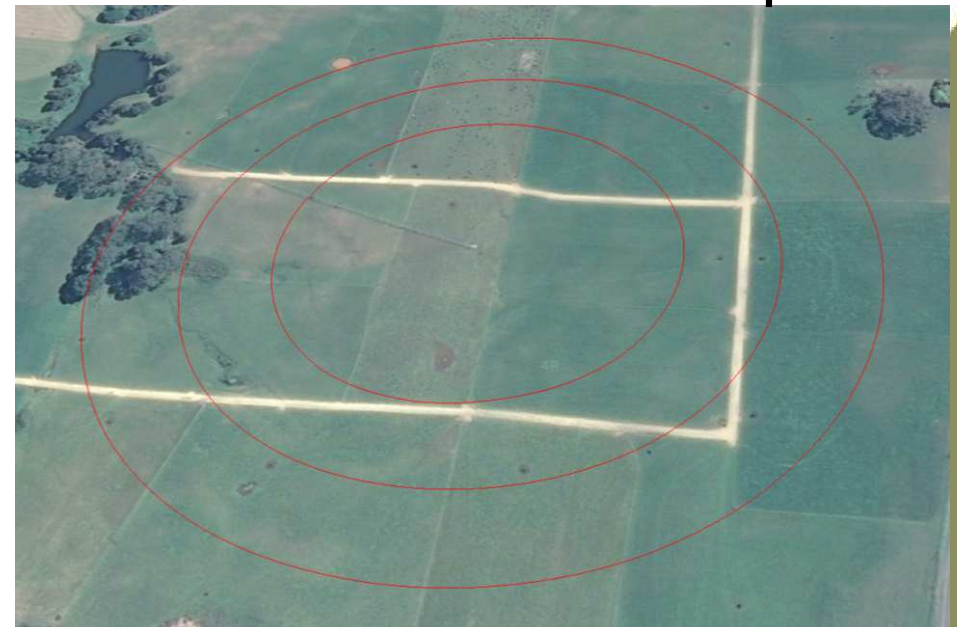
Original image



Analysed image



Location of cameras on pivot



Irrigation advance monitoring

- Thermal and visible camera on 10 m tower
- Upload image on motion detection

Camera tower



Thermal images from head ditch



Grain National Variety Trials

- 630 grain trials across 250 locations
- Manually assessed by Service Providers
- Camera-based detection of flower and height

Wheat variety trial



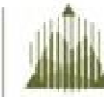
Wheat flowers

Height detection

Camera system



Conclusions



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- Framework developed for data processing at a range of spatial resolutions
- Next steps:
 - Link control strategy output with commercial VRI system for cotton and dairy irrigation sites
 - Online data management and processing for cotton and dairy data and control
 - Evaluation of control strategies at all sites over next two years

Acknowledgements



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