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

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NCEA National Centre for Engineering in Agriculture

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

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National Centre for Engineering in Agriculture
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NCEA's automation research

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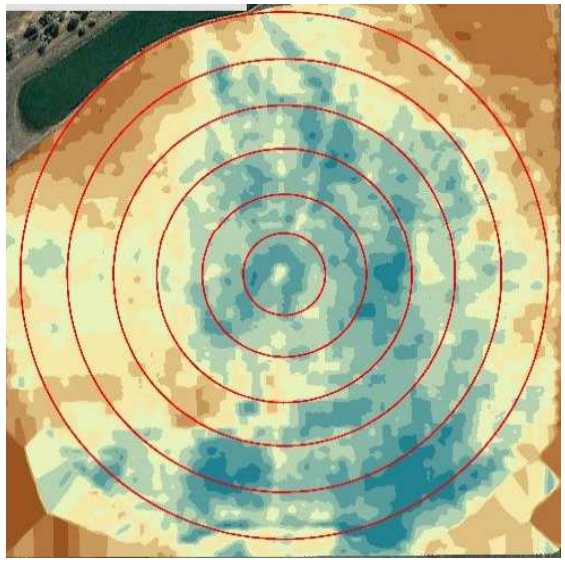
- Machine vision, automation, robotics
- Low cost machine guidance
- Precision monitoring tools

Variable-rate technology for overhead and surface irrigation

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

EM



Pulsing solenoids on VRI

Rubicon automation hardware

Site-specific irrigation control system

Surface irrigation system

Overhead irrigation system

1. Sensors

- fixed sensors
- historical maps
- on-the-go sensors

2. Control strategy

- convert data to irrigation application
- model-based control needs calibration with infield data

3. Real-time irrigation adjustment

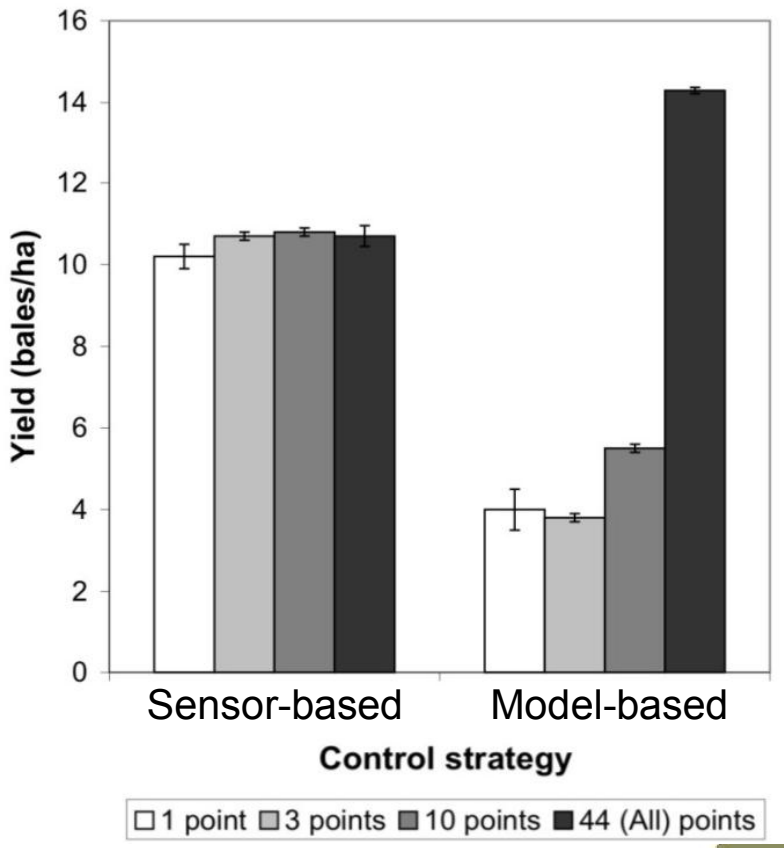
- actuators to apply irrigation

Irrigation automation projects

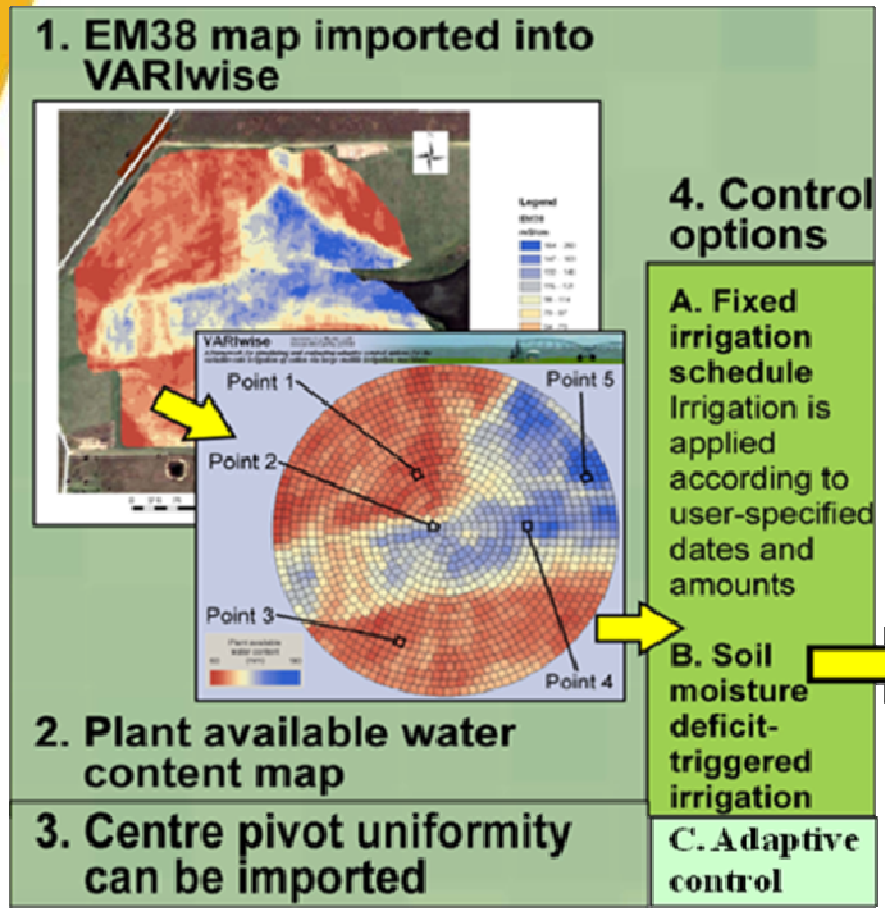
- CRDC research project:
  - Evaluate adaptive control systems for surface irrigated and fertigated cotton
- QLD Government Accelerate Fellowship:
  - Evaluate automated site-specific irrigation for beans and carrots in SE QLD and NZ
- Rural R&D Smarter Irrigation for Profit:
  - Demonstrate automated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

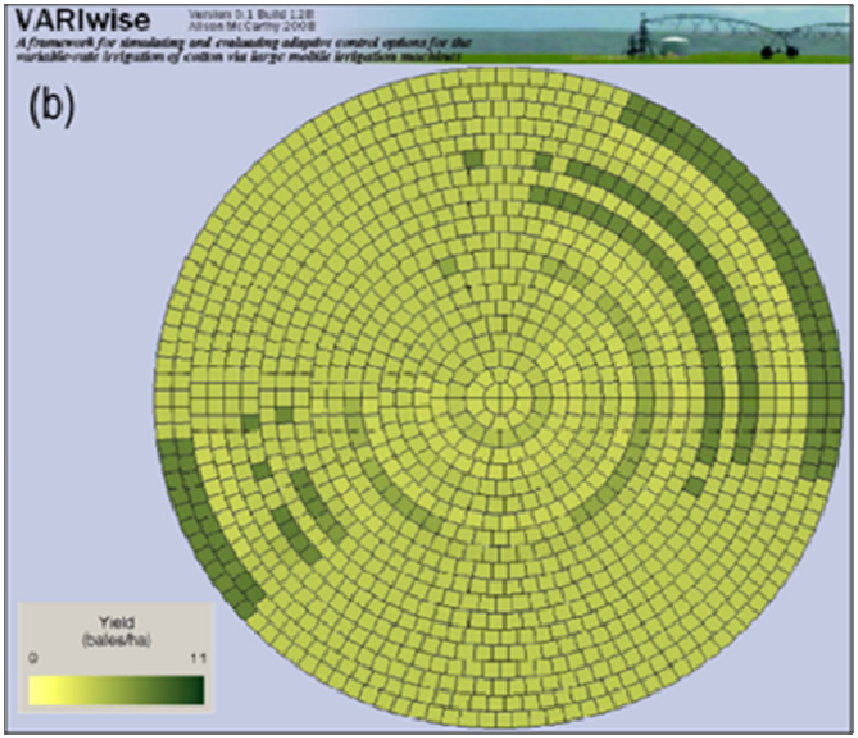
Irrigation control strategies

- 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



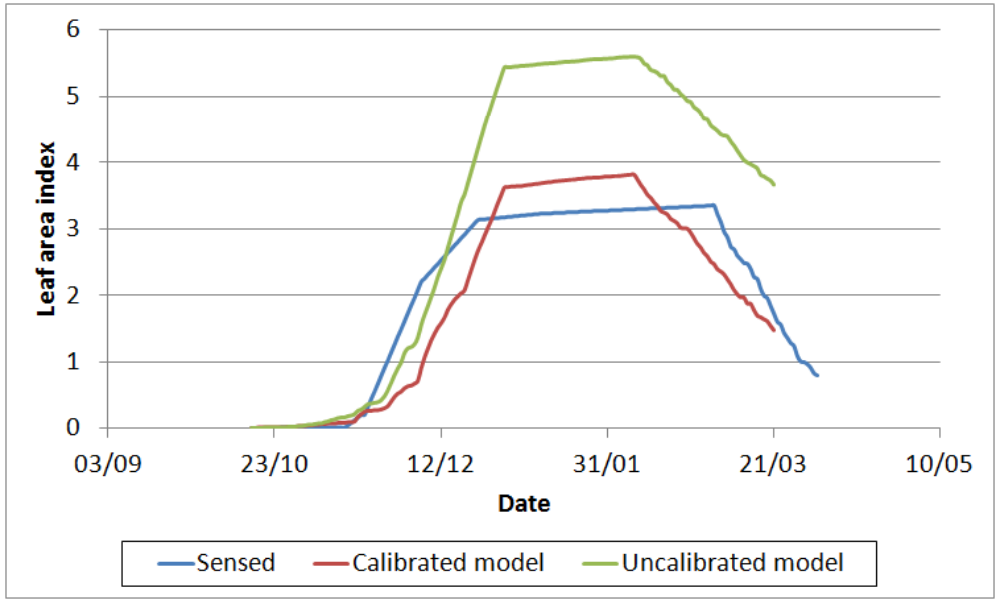


Sensor location	Variability in machine uniformity	Yield (bales/ha)	Irrigation water use efficiency (bales/ML)
Point 1	Low	7.0	0.7
	High	7.0	1.0
Point 2	Low	7.1	0.7
	High	7.0	1.0
Point 3	Low	7.1	0.8
	High	4.6	0.4
Point 4	Low	6.8	0.7
	High	7.0	1.0
Point 5	Low	7.4	0.9
	High	7.0	0.9

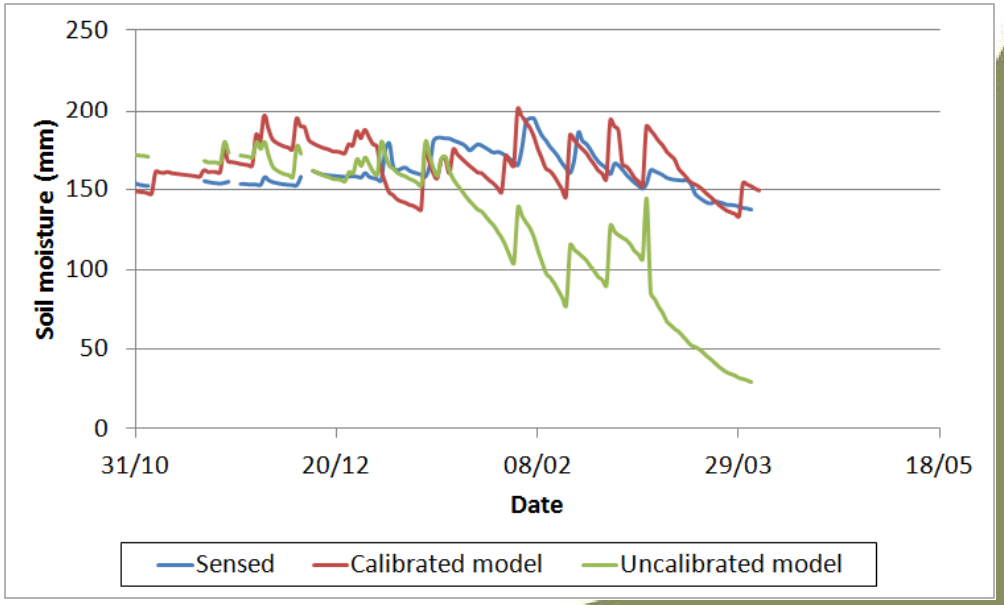
Model calibration

- 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



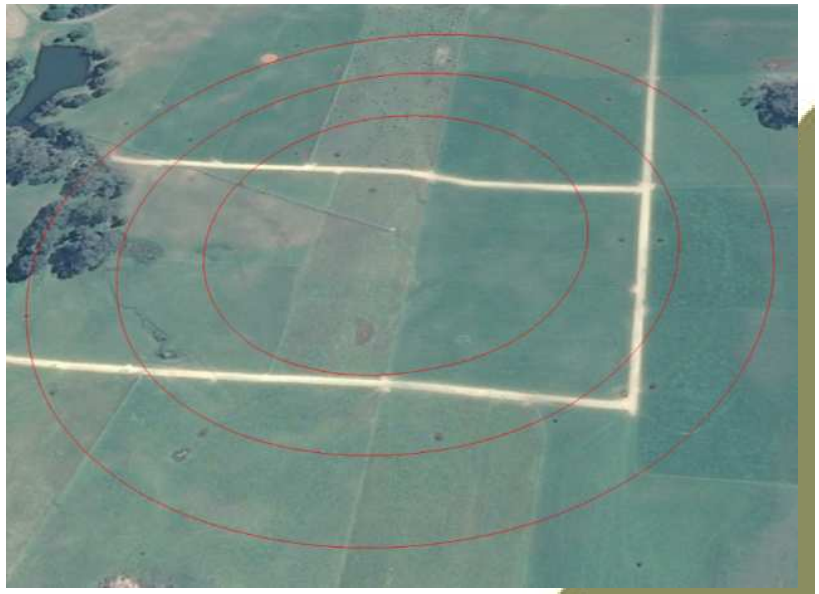
Data pre-processing

- 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

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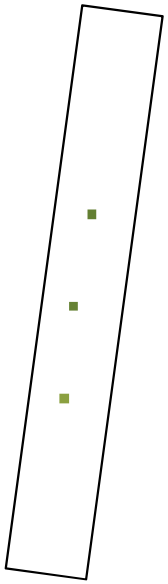
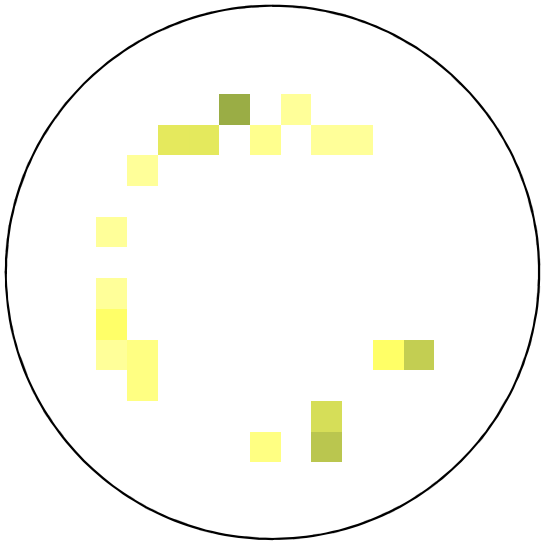
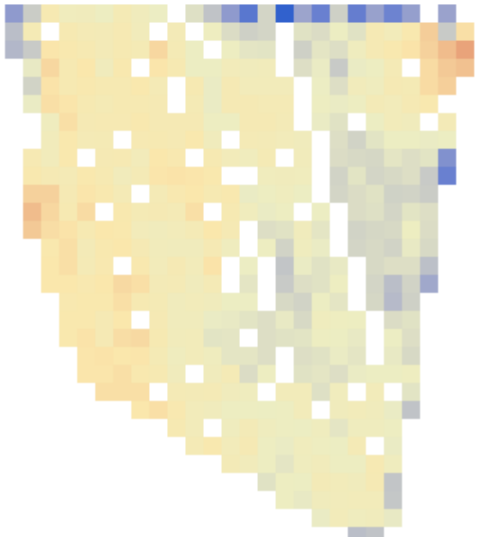
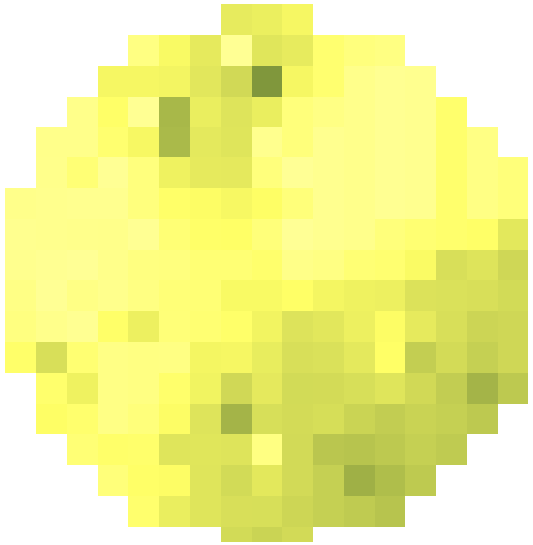
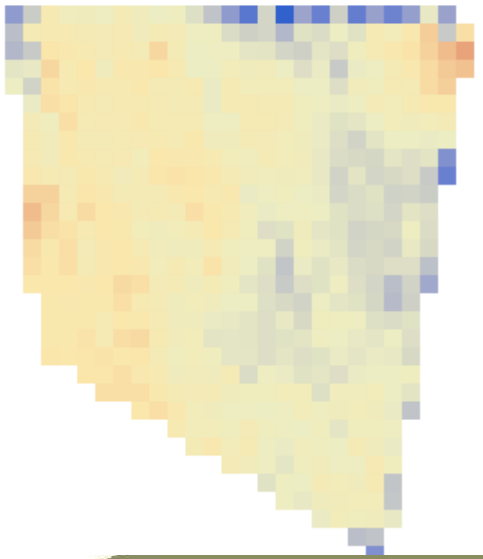
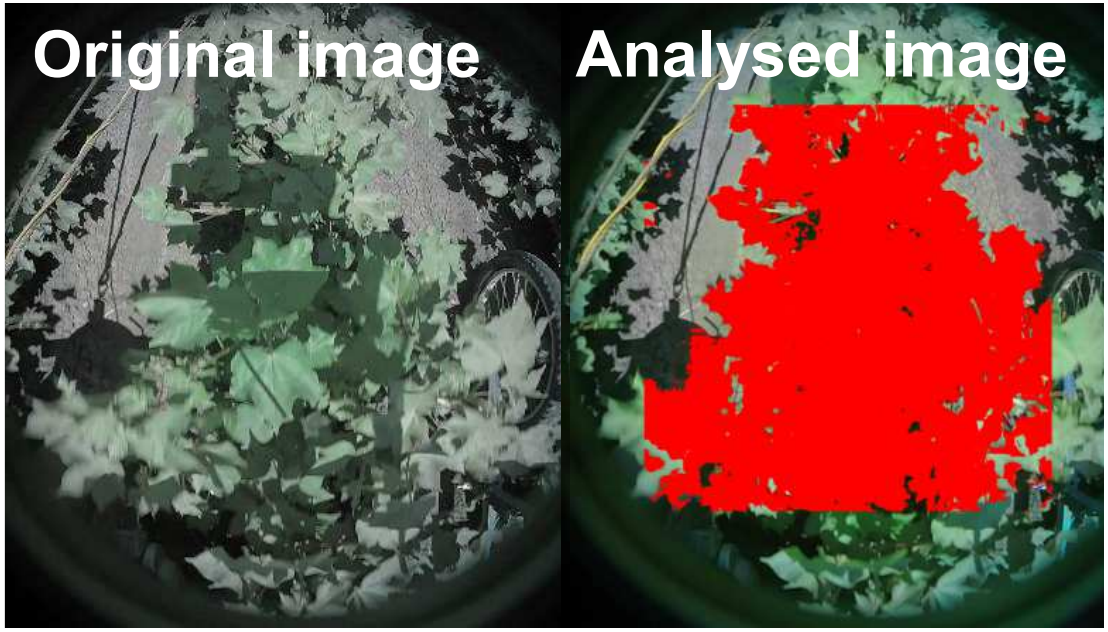
	Single points	On-the-go	Mapped
Before interpolation			
After interpolation			

Image data input

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



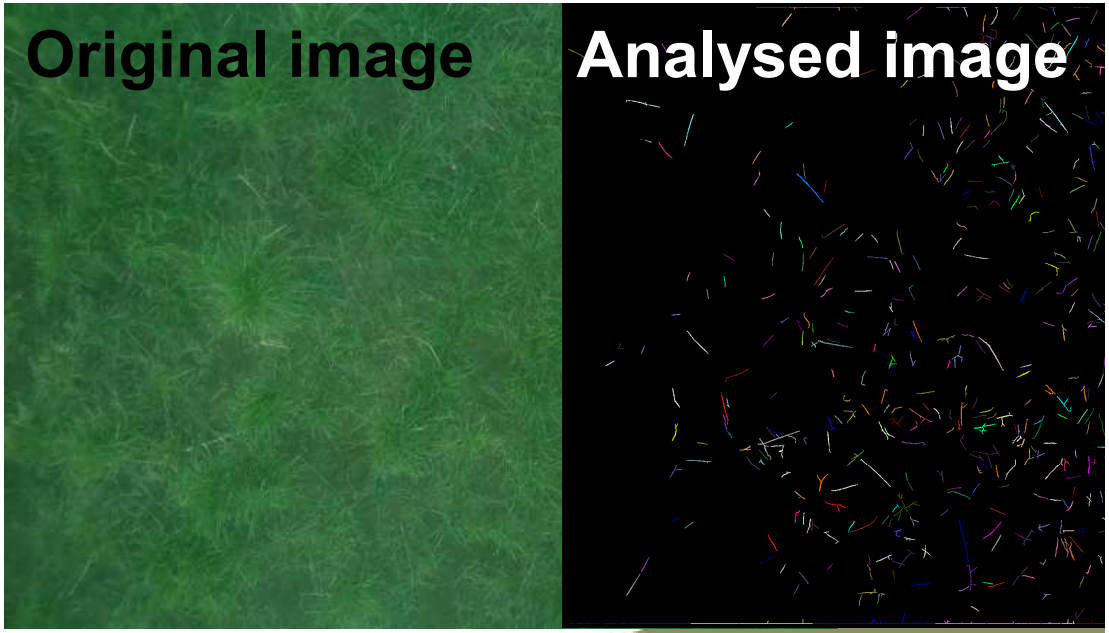
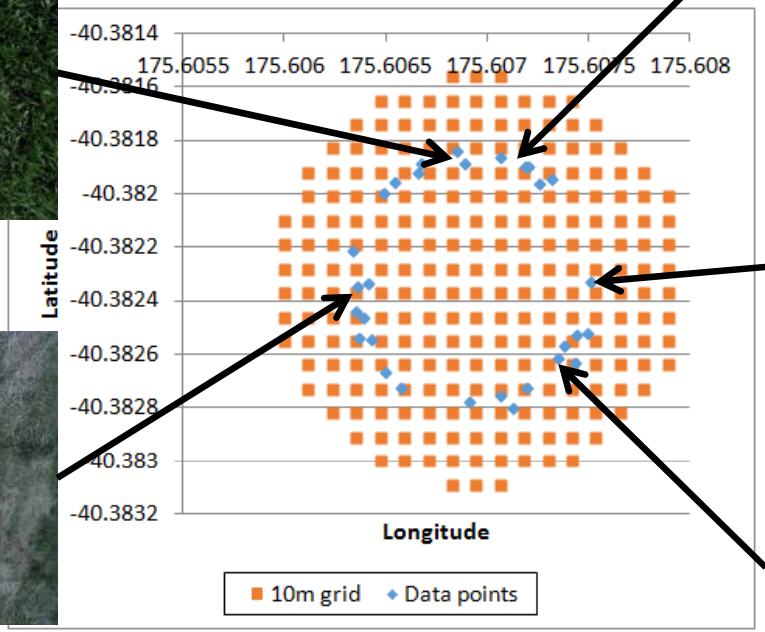


Image data pre-processing

1. Collect images and location



2. Analyse images

3. Interpolate map

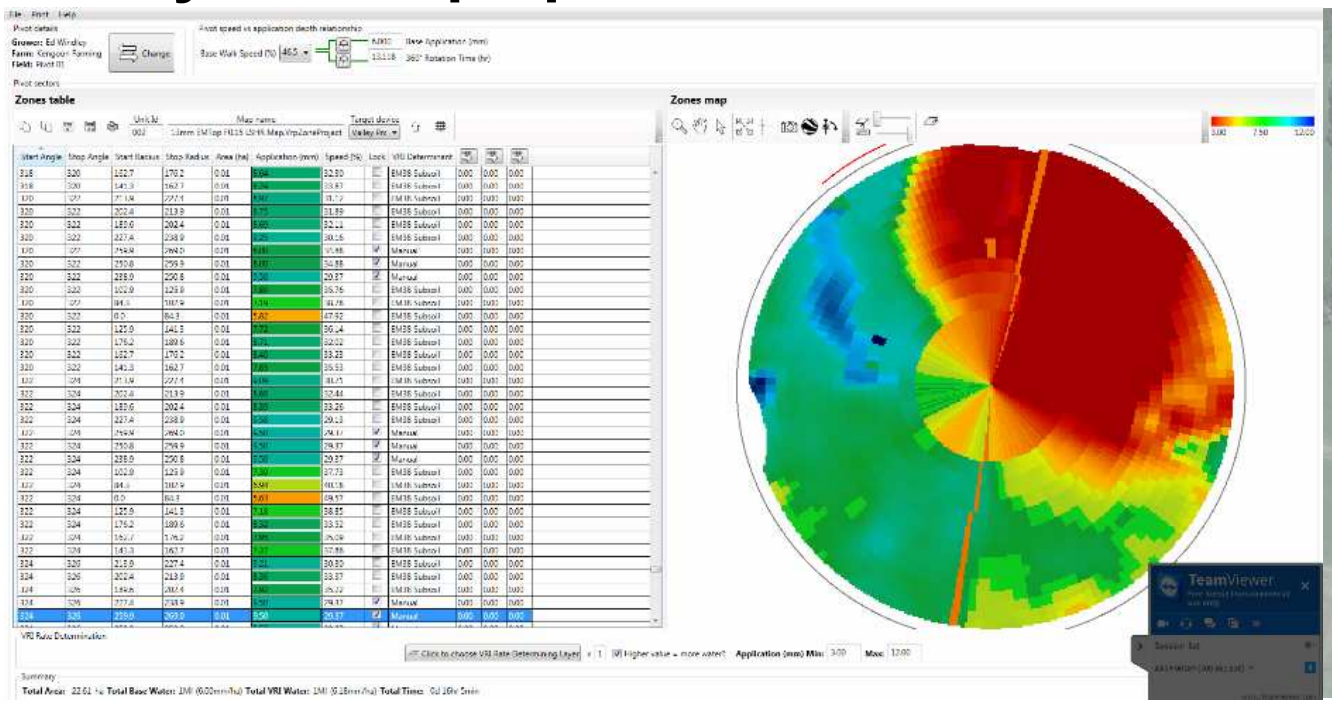
0 Cover (%) 100

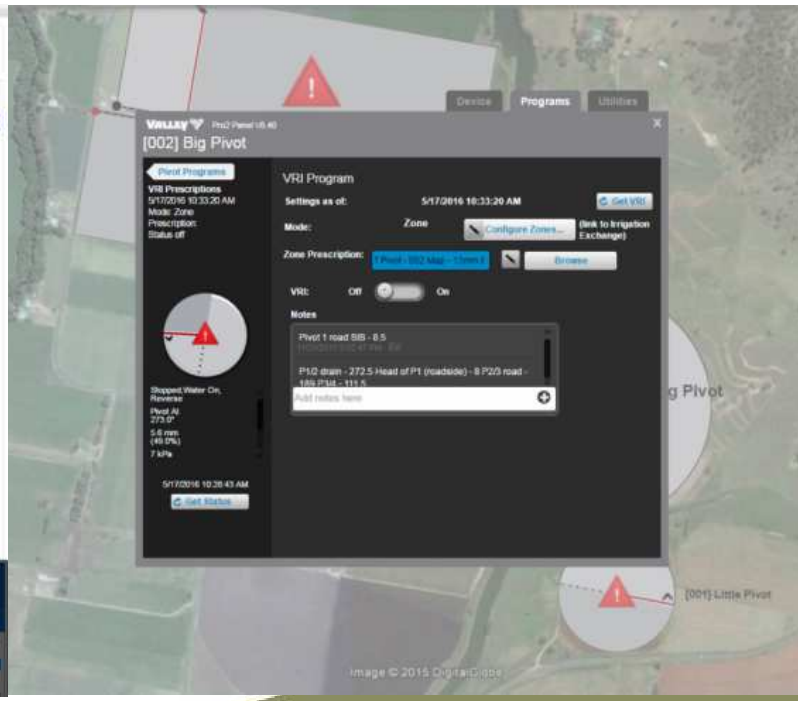
Upload map to VRI system

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:





Control system implementation on centre pivot

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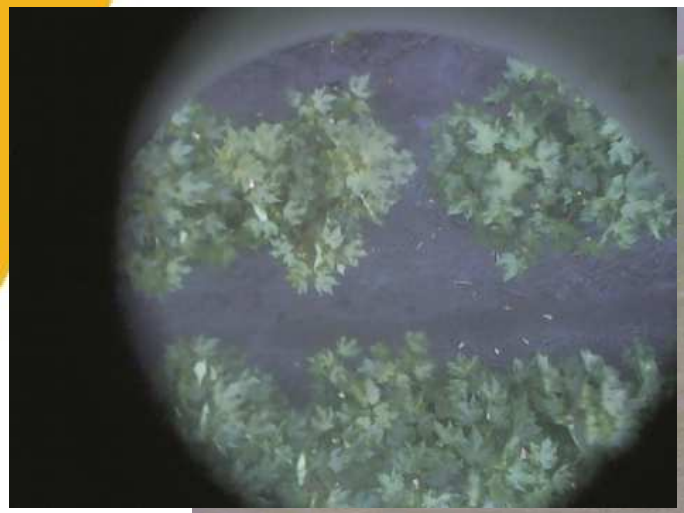
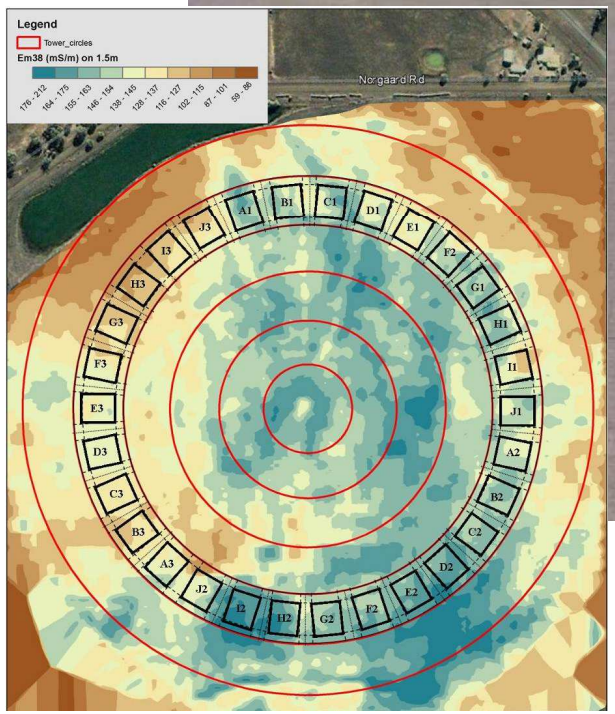
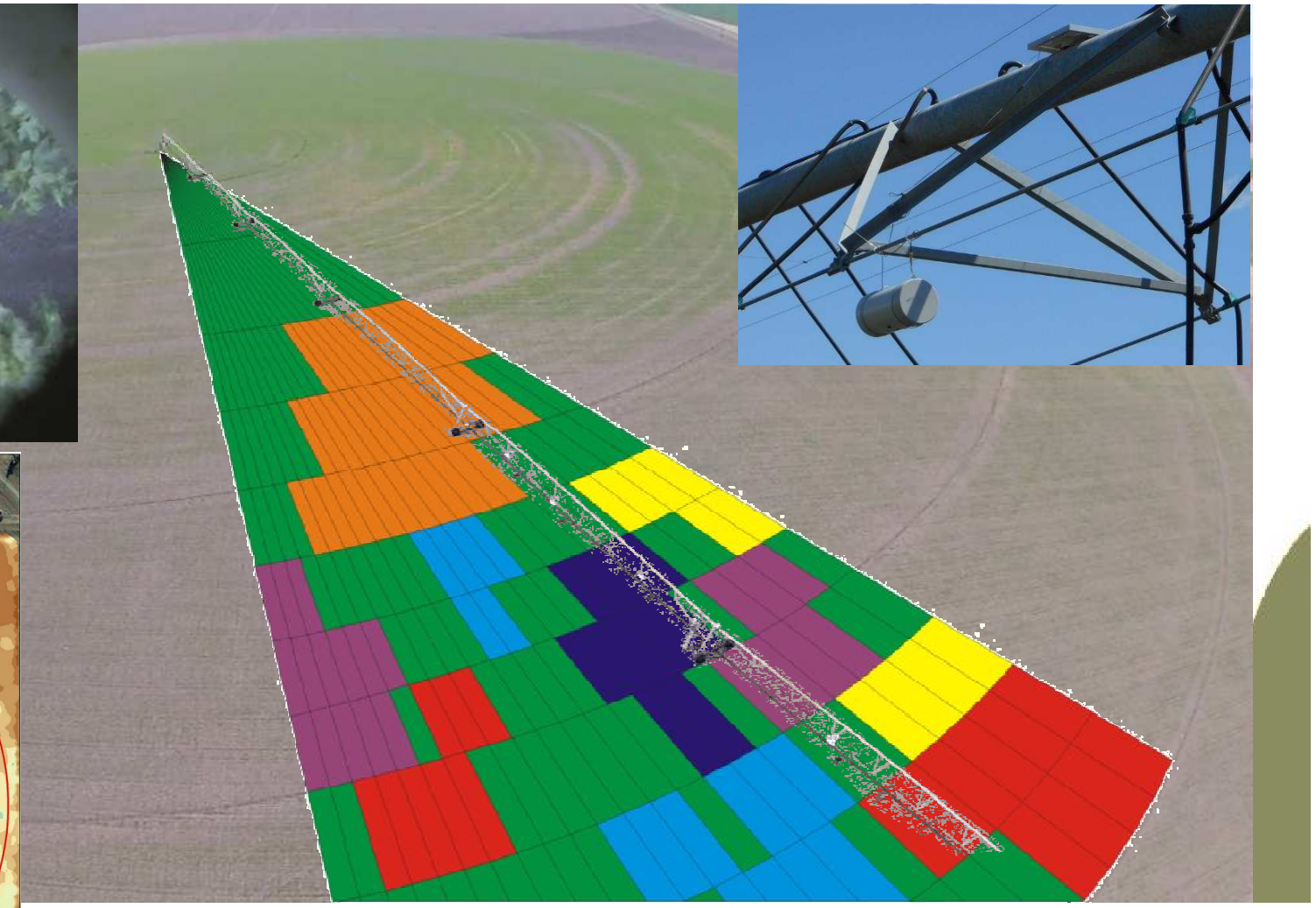
Real-time camera-based plant sensing to update irrigation:

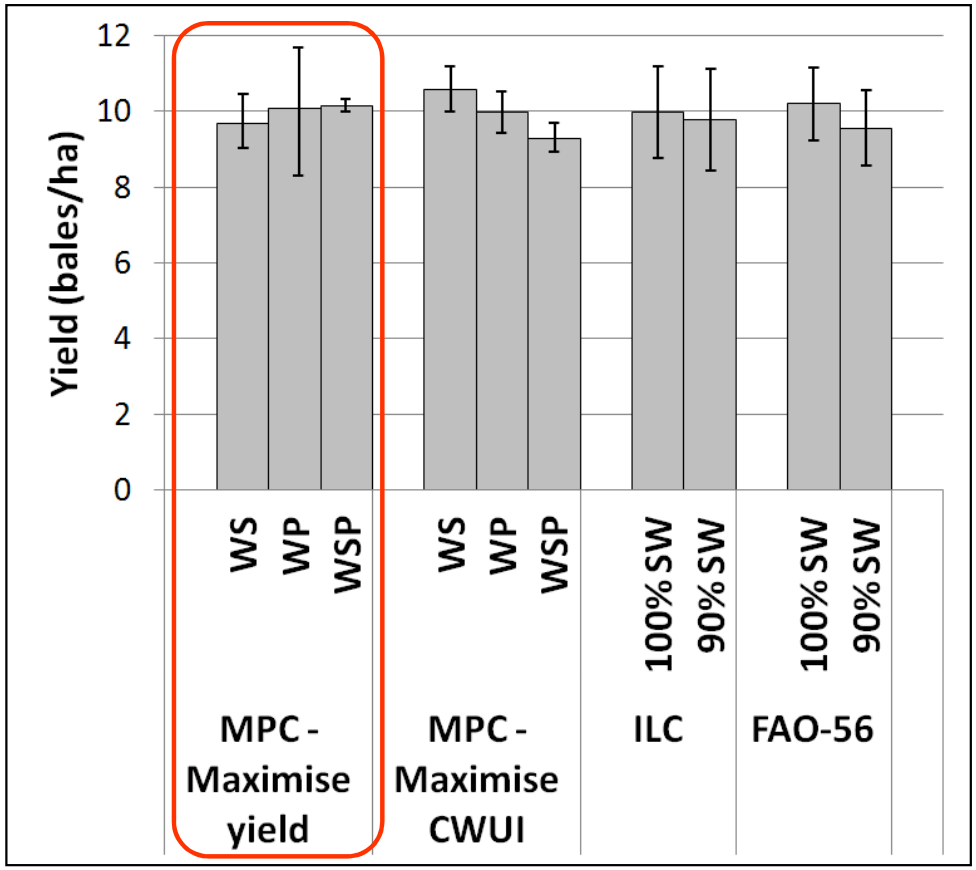


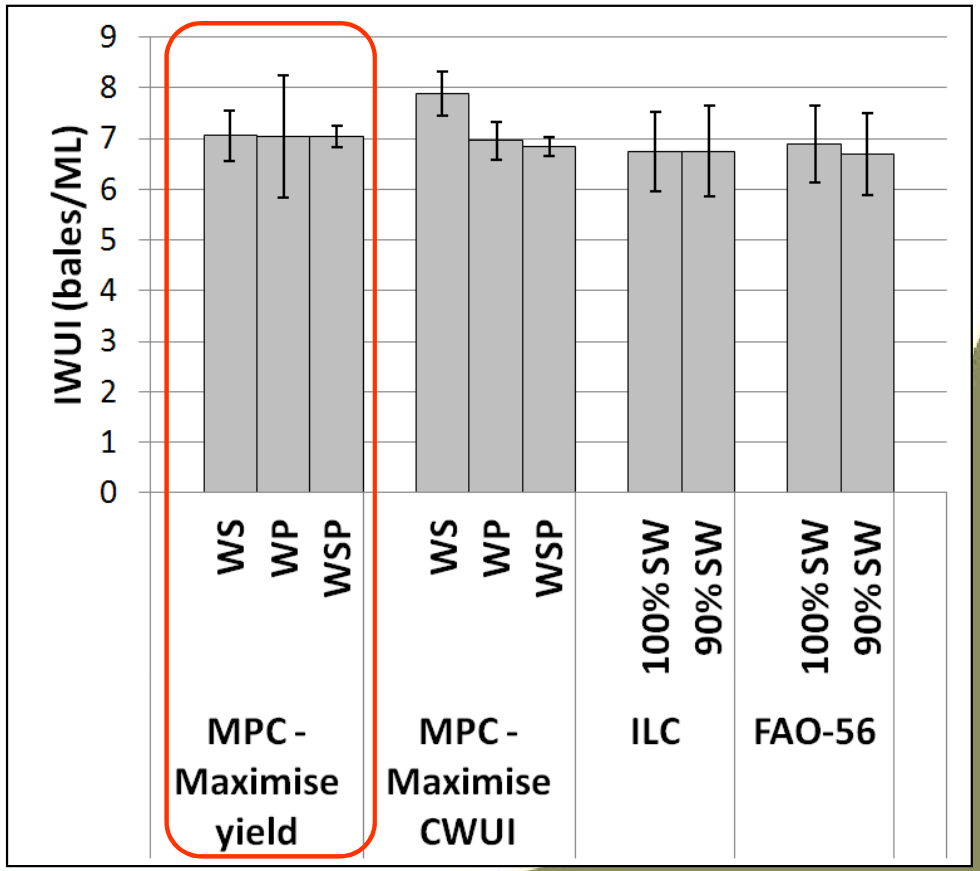




Centre pivot trial – MPC yield

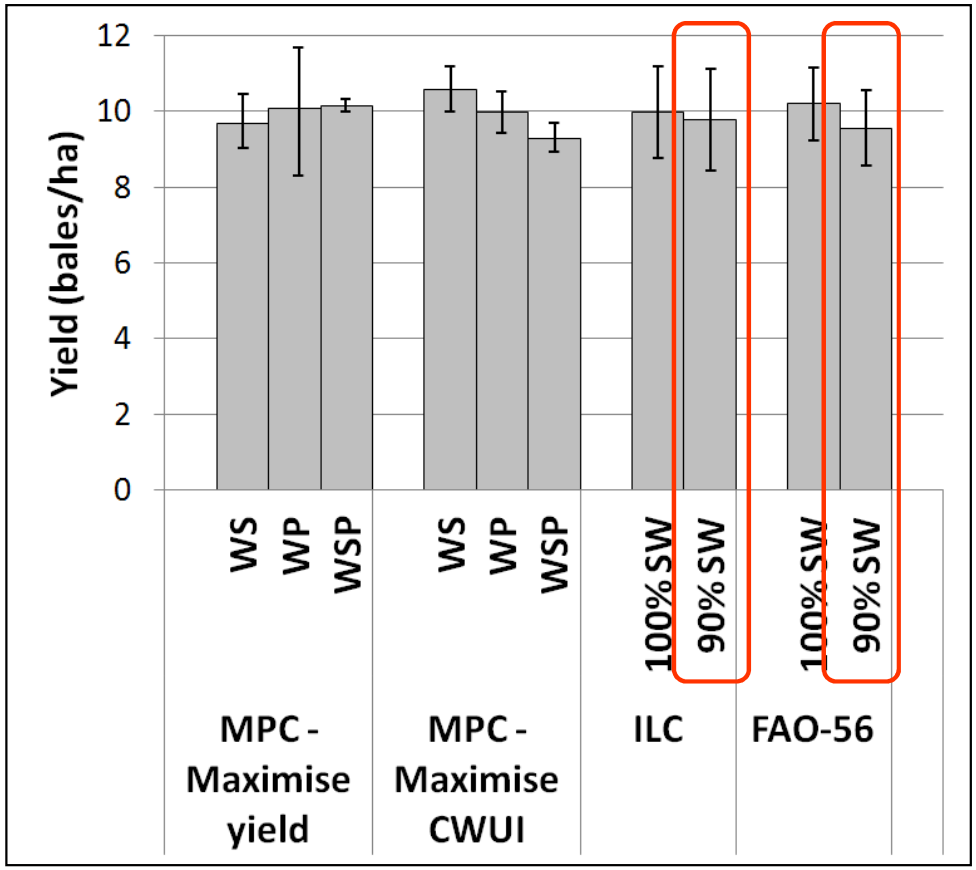
- Plant data input led to higher yield, no change in IWUI
  - ➢ Plant data input increased yield for MPC maximising yield

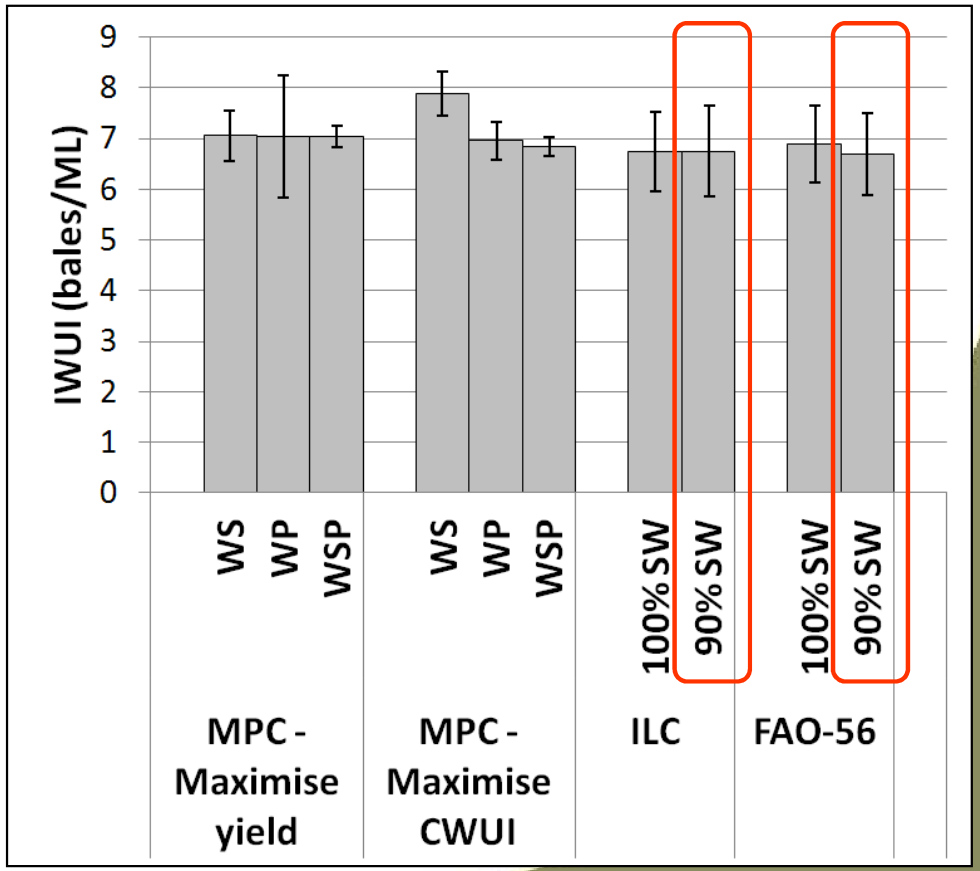




Centre pivot trial – sensors

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





Control system implementation for surface irrigation

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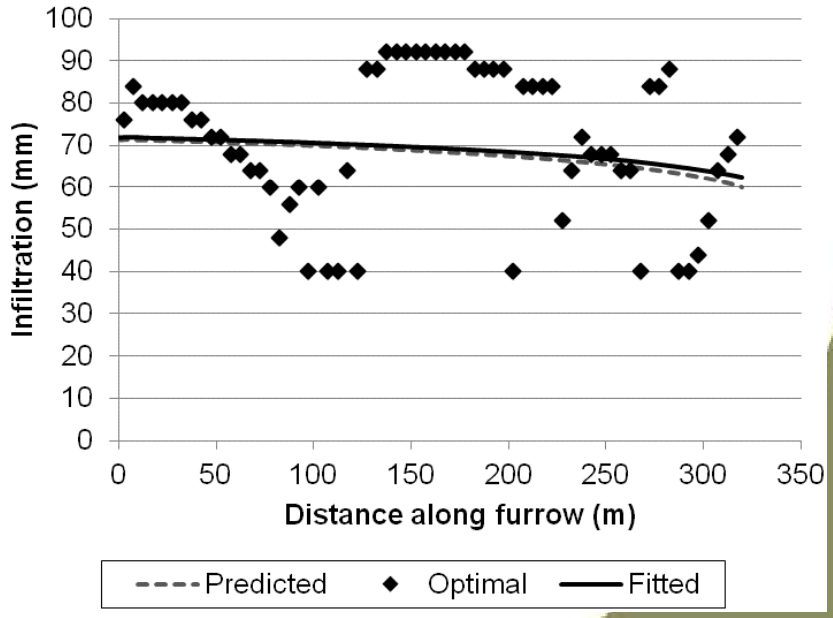
Crop growth and fruiting sensing using cameras

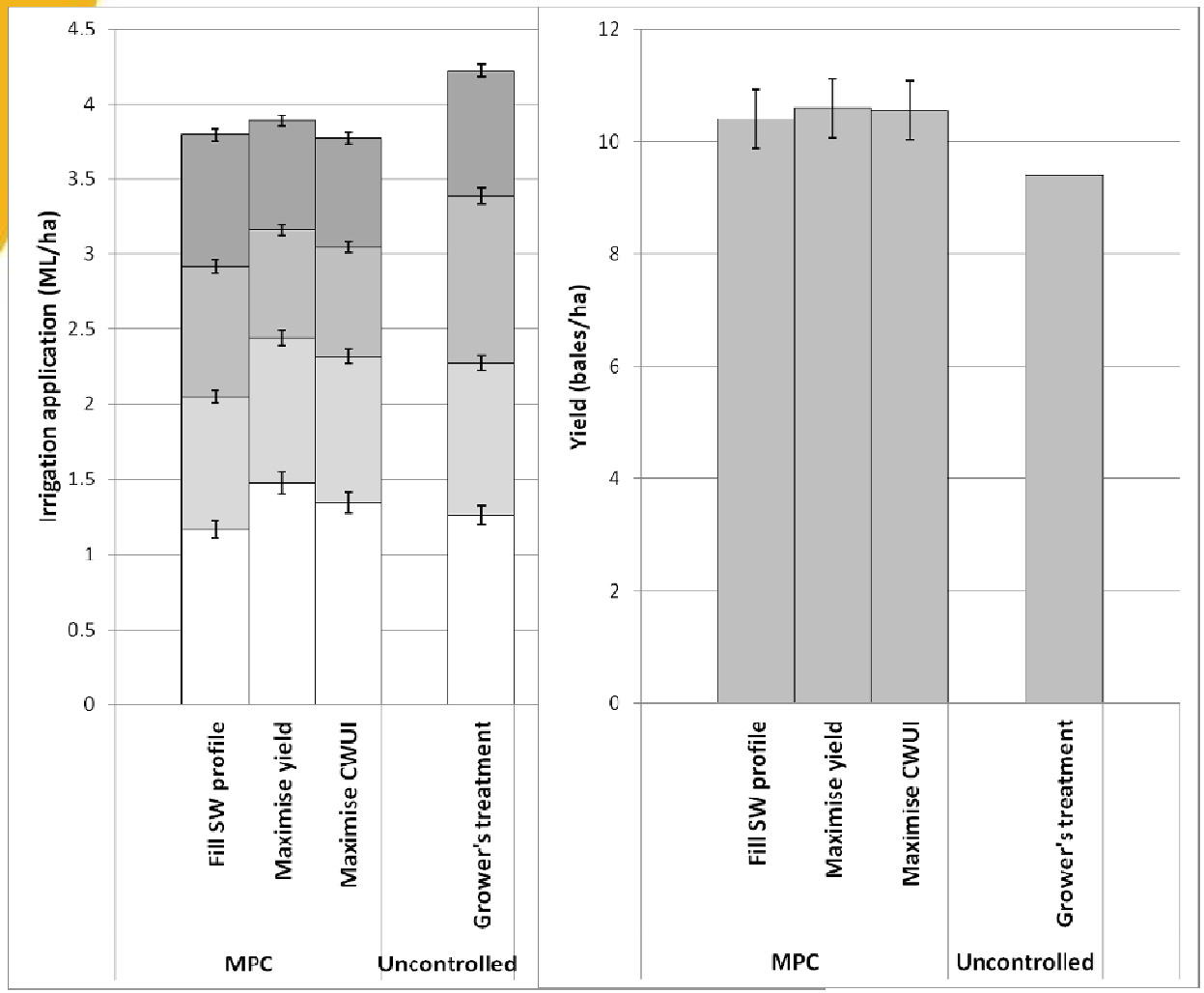
Soil-water, weather

Control strategy determines irrigation along furrows

Determine flow rate and cut-off time

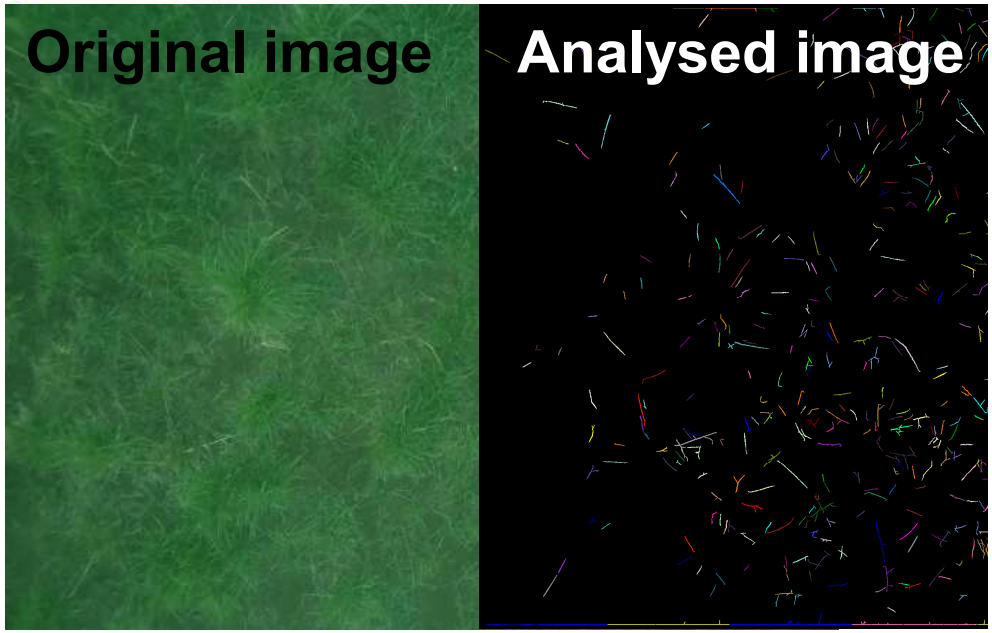


Surface irrigation trial



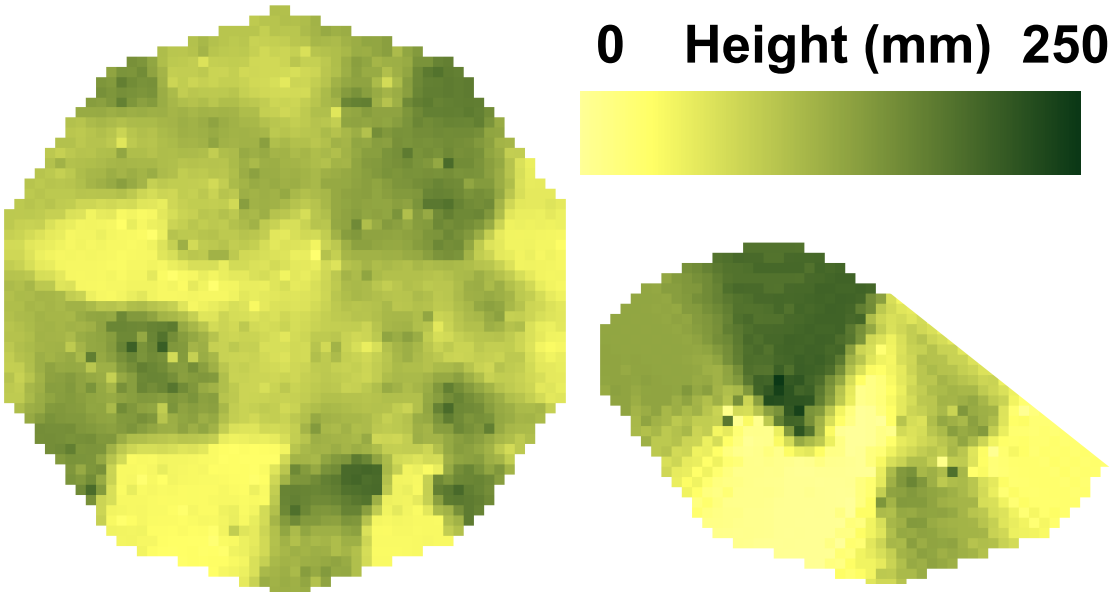
Automated irrigation for dairy pastures

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

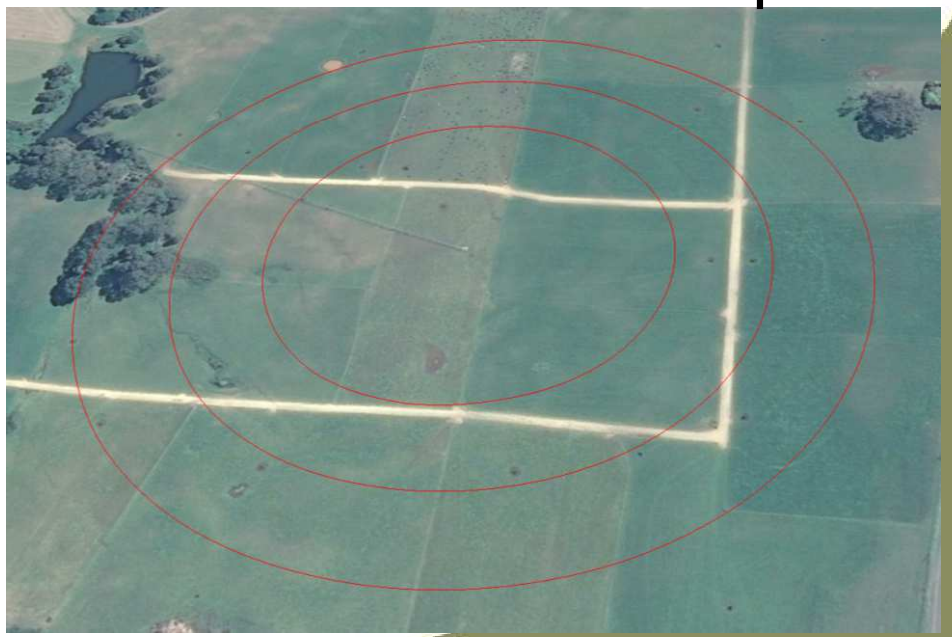


Height from quad bike sensor

Canopy cover from cameras



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

- 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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