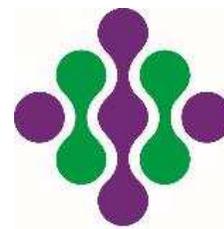


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Australian Government
Department of Agriculture
and Water Resources



Australian Government
Cotton Research and
Development Corporation



**Dairy
Australia**

Automated camera-based crop monitoring and site-specific irrigation control systems

Dr Alison McCarthy, mccarthy@usq.edu.au

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



Site-specific irrigation

- Can be over 200% variation in irrigation requirements: soil water holding capacity, elevation
- Variable-rate irrigation (VRI) hardware and variability mapping can be used

Dairy pasture in Tasmania:

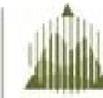


Horticulture field in Kalbar:



VRI research

- Research trials in horticulture, corn, pasture and cotton in Australia, New Zealand and USA
- Inputs include soil type, soil moisture, temperature, crop growth



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Soil moisture network in NZ:



IRTs in Texas:



Cameras in QLD:



Commercial VRI use

- Cost about \$1500/ha – includes VRI hardware, GPS, software, remote access
- Generally 0-20% yield increase or water reduction reported in literature
- Generally used for avoiding roads
- Only 10% of VRI purchased still used



VRI hardware

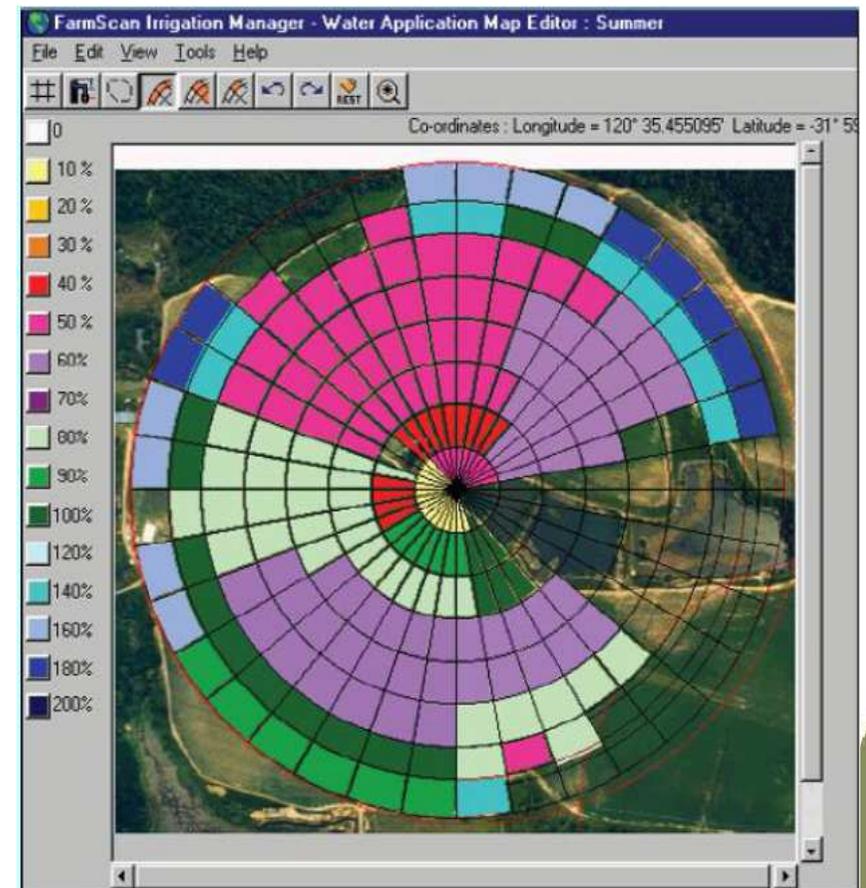
- Solenoid valve on each dropper
- Zones controlled with pulse width modulation and speed control to adjust flow rate
- Valley, Lindsay Zimmatic, Reinke, Trimble



Prescription map development



- For centre pivots, field divided into 1° sectors and zones along machine
- Original VRI systems needed manual entry of irrigation volume into individual zones
- Now polygons define zones



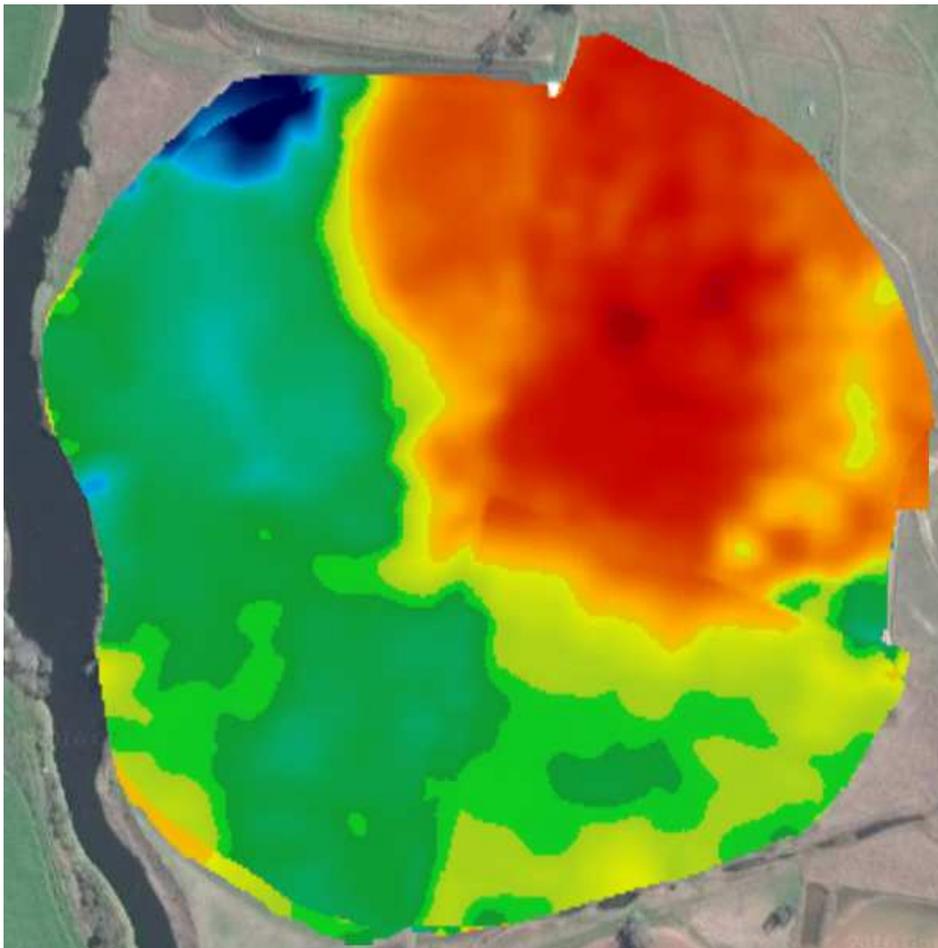
Prescription map development



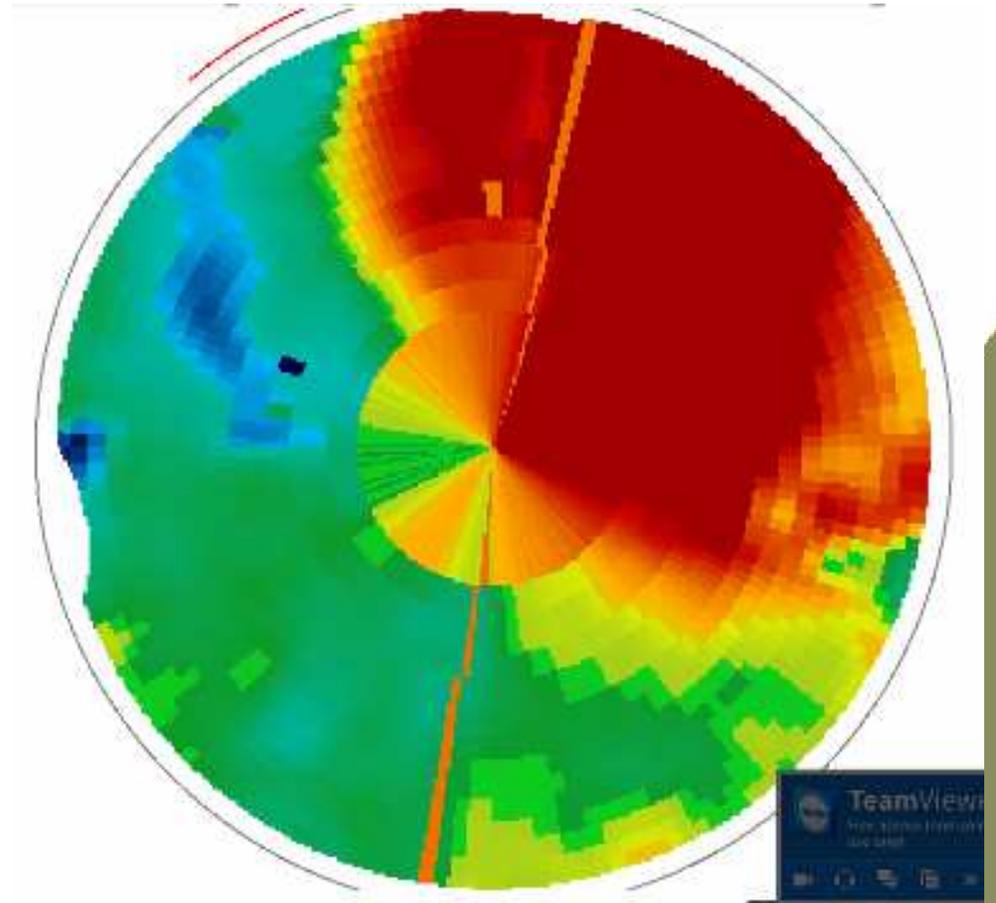
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- Field map imported into data management software e.g. PCT, SST

Original map:



VRI map:



Prescription map development



- Zone-by-zone editing of prescription map

Zone prescription input:

VRI map:

Avot speed vs application depth relationship

Base Walk Speed (D) 465

ADWD Base Application (mm) 131.18

360° Rotation Time (hr)

Zones table

Start Angle	Stop Angle	Start Radius	Stop Radius	Area (ha)	Application (mm)	Speed (K)	Lock	VRI Determinant			
318	320	162.7	170.2	0.01	808	32.30		EM38 Subsoil	0.00	0.00	0.00
318	320	141.3	162.7	0.01	828	33.87		EM38 Subsoil	0.00	0.00	0.00
120	122	211.9	227.1	0.01	834	31.73		EM38 Subsoil	0.00	0.00	0.00
320	322	202.4	213.8	0.01	871	31.89		EM38 Subsoil	0.00	0.00	0.00
320	322	189.0	202.4	0.01	860	32.11		EM38 Subsoil	0.00	0.00	0.00
320	322	227.4	238.9	0.01	820	30.15		EM38 Subsoil	0.00	0.00	0.00
120	122	194.9	204.0	0.01	811	31.98		Manual	0.00	0.00	0.00
320	322	250.8	259.9	0.01	700	30.85		Manual	0.00	0.00	0.00
320	322	236.0	250.8	0.01	820	29.87		Manual	0.00	0.00	0.00
320	322	102.9	125.9	0.01	880	35.75		EM38 Subsoil	0.00	0.00	0.00
120	122	84.6	107.9	0.01	834	41.78		EM38 Subsoil	0.00	0.00	0.00
320	322	0.0	64.3	0.01	803	47.82		EM38 Subsoil	0.00	0.00	0.00
320	322	125.0	141.3	0.01	873	36.44		EM38 Subsoil	0.00	0.00	0.00
320	322	176.2	189.0	0.01	821	32.02		EM38 Subsoil	0.00	0.00	0.00
320	322	162.7	170.2	0.01	840	33.22		EM38 Subsoil	0.00	0.00	0.00
320	322	141.3	162.7	0.01	860	35.93		EM38 Subsoil	0.00	0.00	0.00
122	124	211.9	227.1	0.01	834	31.73		EM38 Subsoil	0.00	0.00	0.00
322	324	202.4	213.8	0.01	860	32.44		EM38 Subsoil	0.00	0.00	0.00
322	324	189.0	202.4	0.01	830	33.26		EM38 Subsoil	0.00	0.00	0.00
322	324	227.4	238.9	0.01	838	29.13		EM38 Subsoil	0.00	0.00	0.00
122	124	194.9	204.0	0.01	861	24.17		Manual	0.00	0.00	0.00
322	324	250.8	259.9	0.01	820	29.87		Manual	0.00	0.00	0.00
322	324	236.0	250.8	0.01	820	29.87		Manual	0.00	0.00	0.00
322	324	102.9	125.9	0.01	870	37.75		EM38 Subsoil	0.00	0.00	0.00
122	124	84.6	107.9	0.01	834	41.78		EM38 Subsoil	0.00	0.00	0.00
322	324	0.0	64.3	0.01	803	49.77		EM38 Subsoil	0.00	0.00	0.00
322	324	125.0	141.3	0.01	818	38.85		EM38 Subsoil	0.00	0.00	0.00
322	324	176.2	189.0	0.01	823	33.52		EM38 Subsoil	0.00	0.00	0.00
122	124	162.7	176.2	0.01	836	28.09		EM38 Subsoil	0.00	0.00	0.00
322	324	141.3	162.7	0.01	837	37.86		EM38 Subsoil	0.00	0.00	0.00
324	326	212.9	227.4	0.01	821	30.30		EM38 Subsoil	0.00	0.00	0.00
324	326	202.4	213.8	0.01	838	33.87		EM38 Subsoil	0.00	0.00	0.00
124	126	184.6	202.4	0.01	840	36.22		EM38 Subsoil	0.00	0.00	0.00
124	126	227.4	238.9	0.01	840	24.17		Manual	0.00	0.00	0.00
324	326	259.9	269.0	0.01	820	29.87		Manual	0.00	0.00	0.00

VRI Rate Determination

Click to choose VRI Rate Determining Layer | 1 | Higher value = more water? Application (mm) Min: 300 Max: 1200

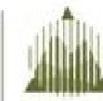
Summary
Total Area: 22.61 ha Total Base Water: 1M (600mm/ha) Total VRI Water: 1M (120mm/ha) Total Time: 0:12:06 Cntrl

Zones map

3.00 7.50 12.00

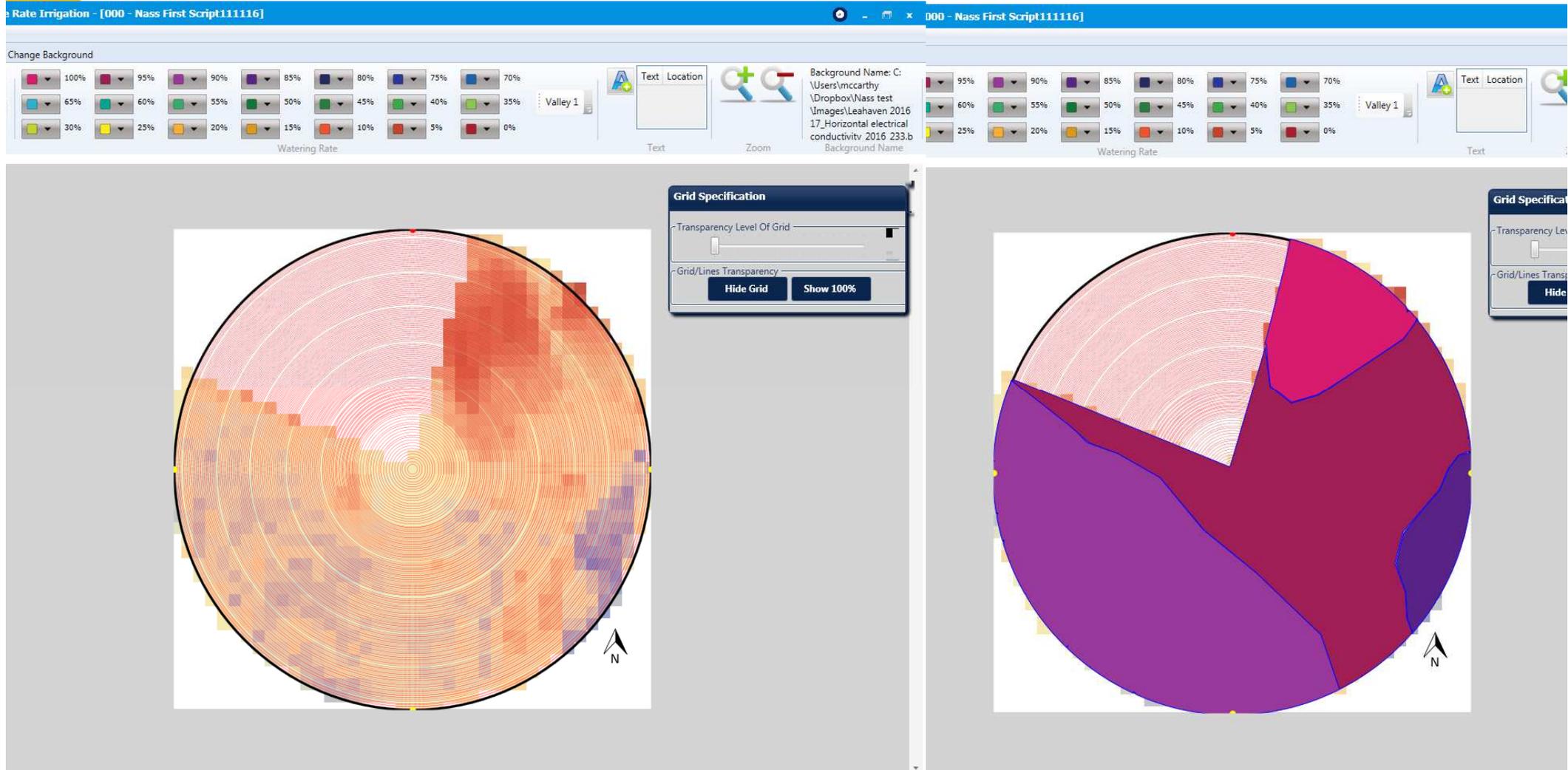
TeamViewer

Prescription map development



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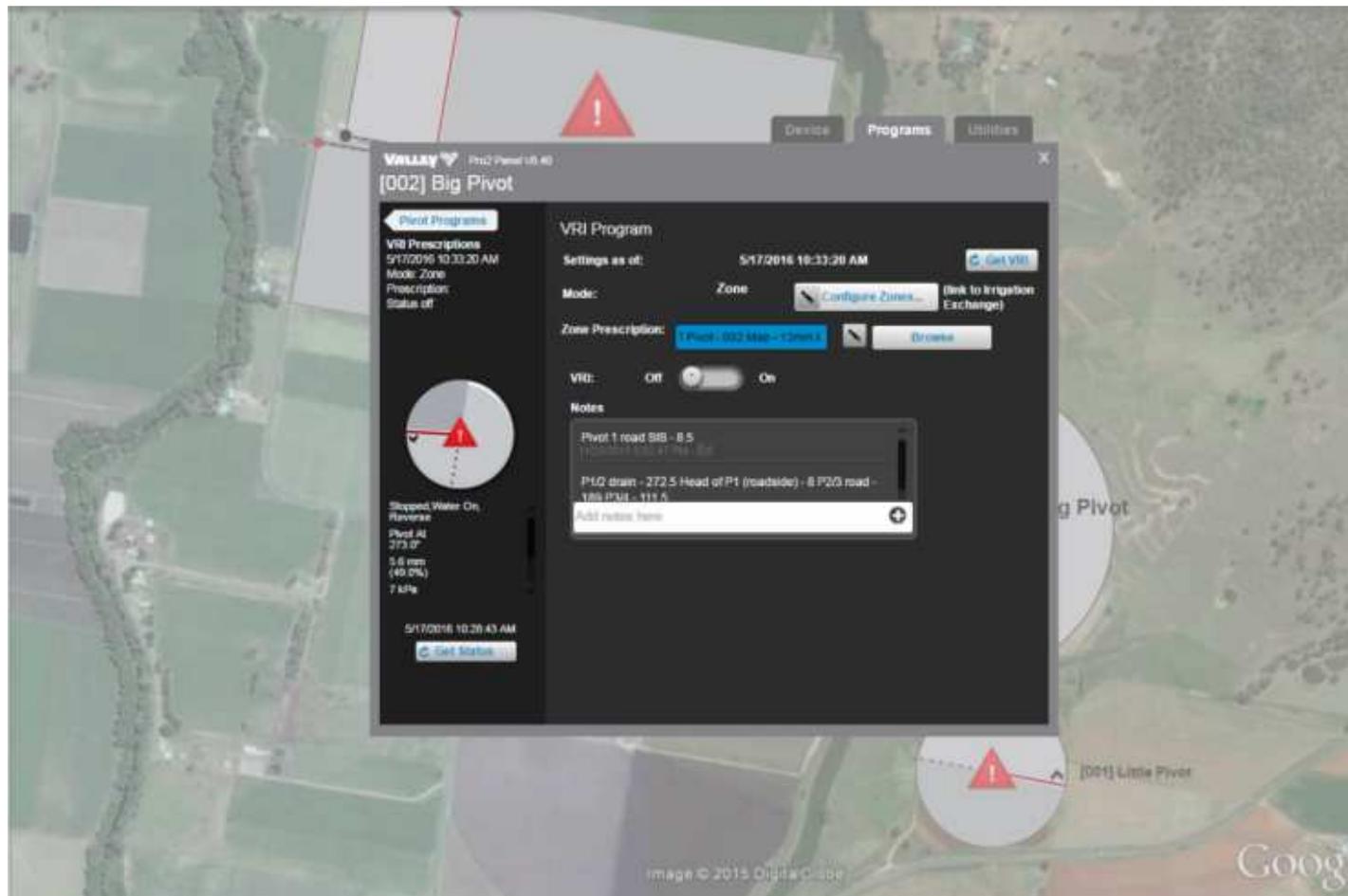
- User draws on polygon to define zones



Upload map to VRI system

- Remote access, radio or manual upload

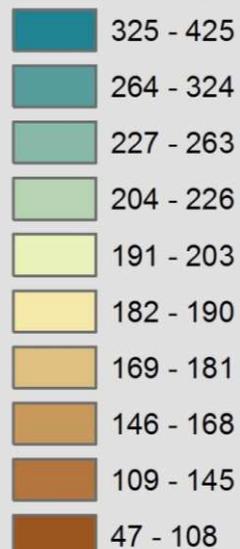
Valley VRI map upload:



Monitoring - soil

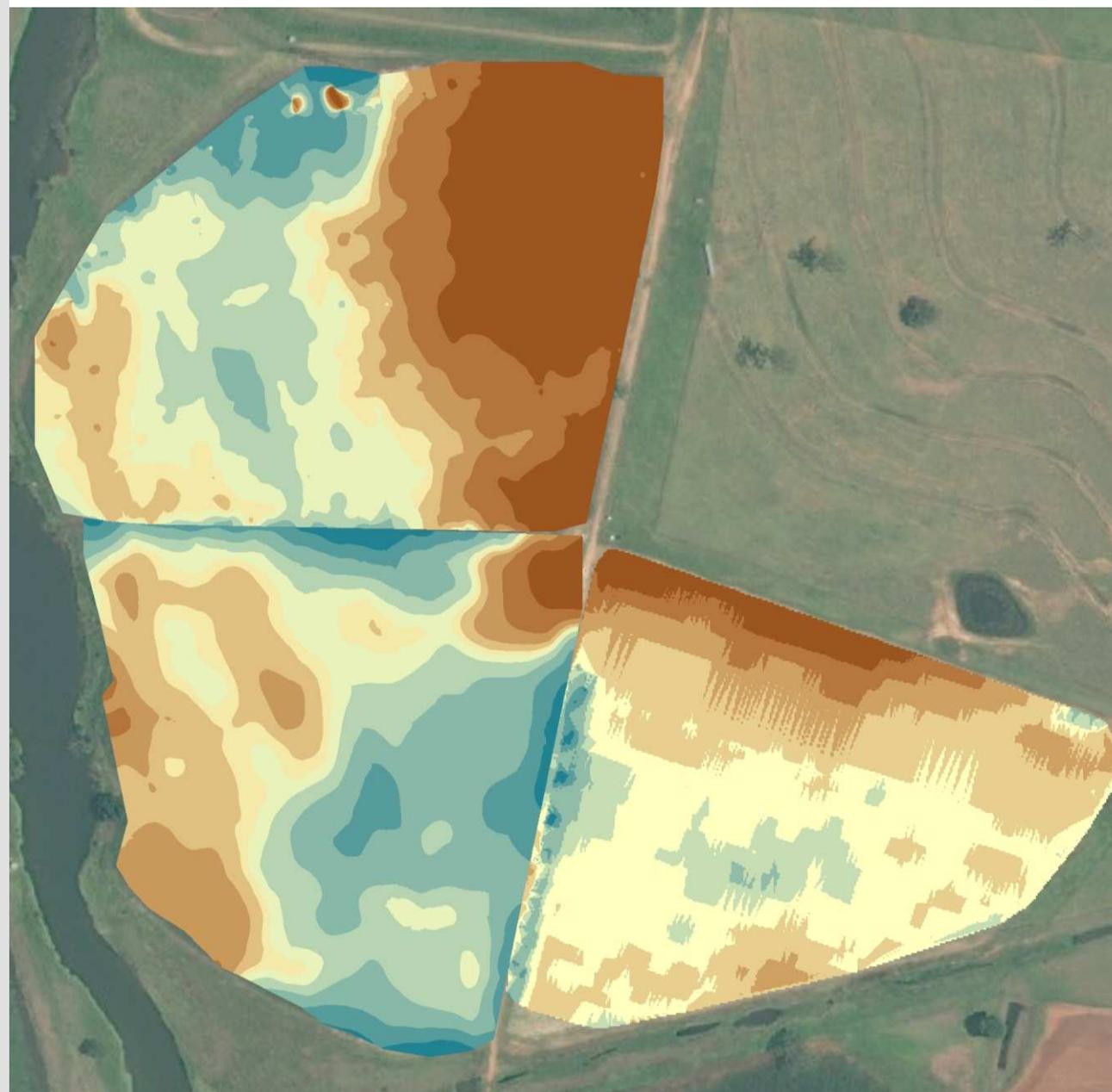
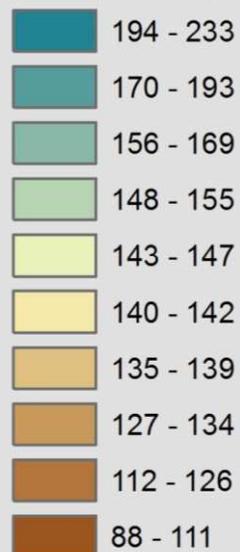
NW_block_vert

ECa (mS/m)



SW_block_vert

ECa (mS/m)



SE_block_vertical

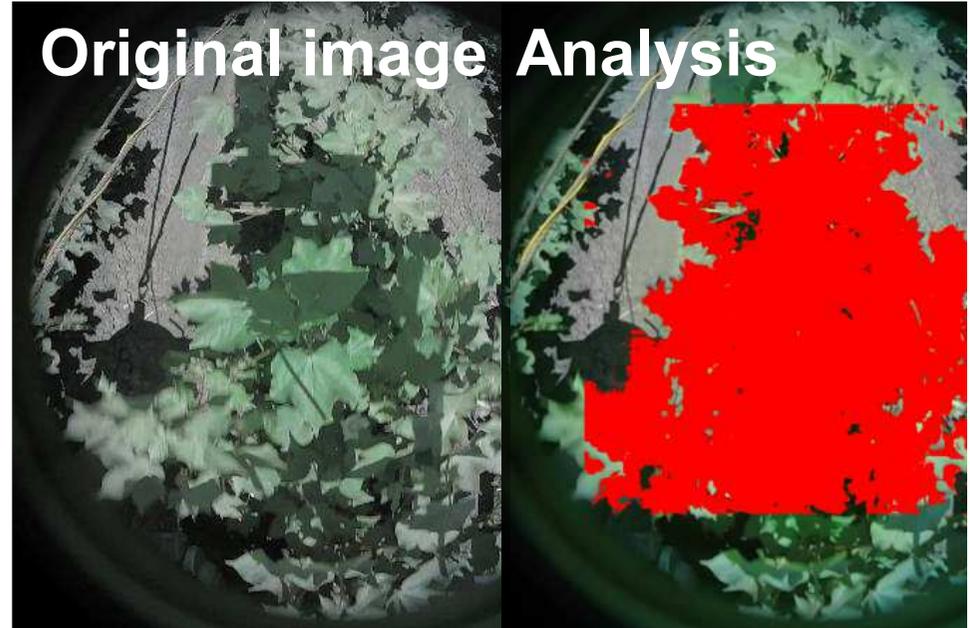
ECa (mS/m)



Monitoring – machine imagery



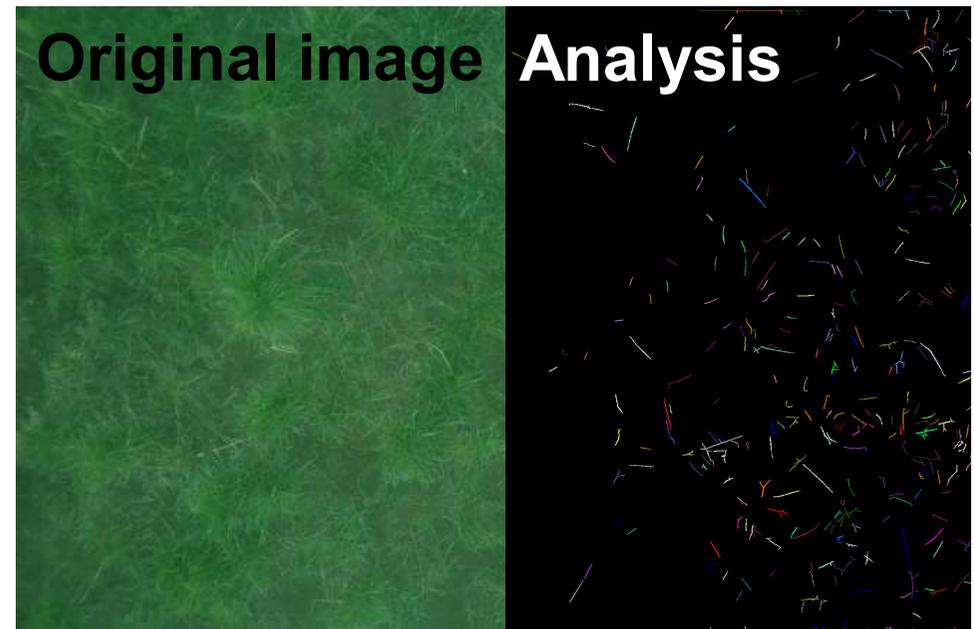
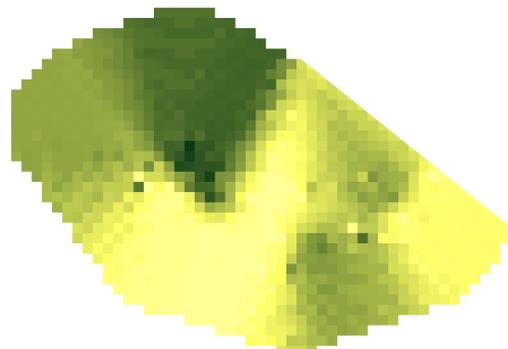
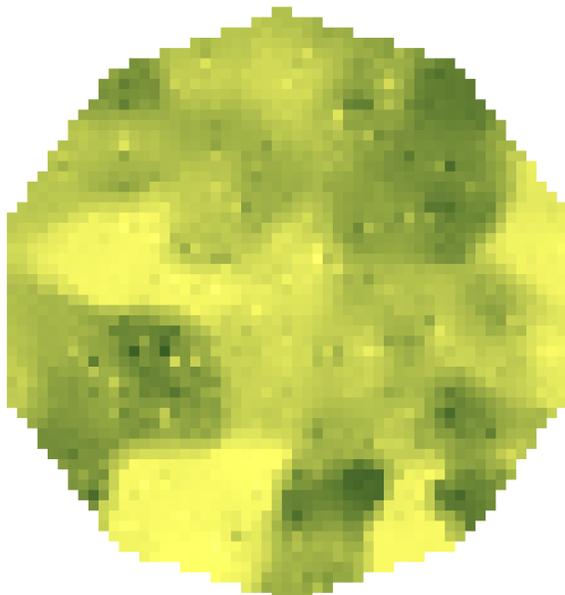
Smartphone camera



Height from quad bike sensor

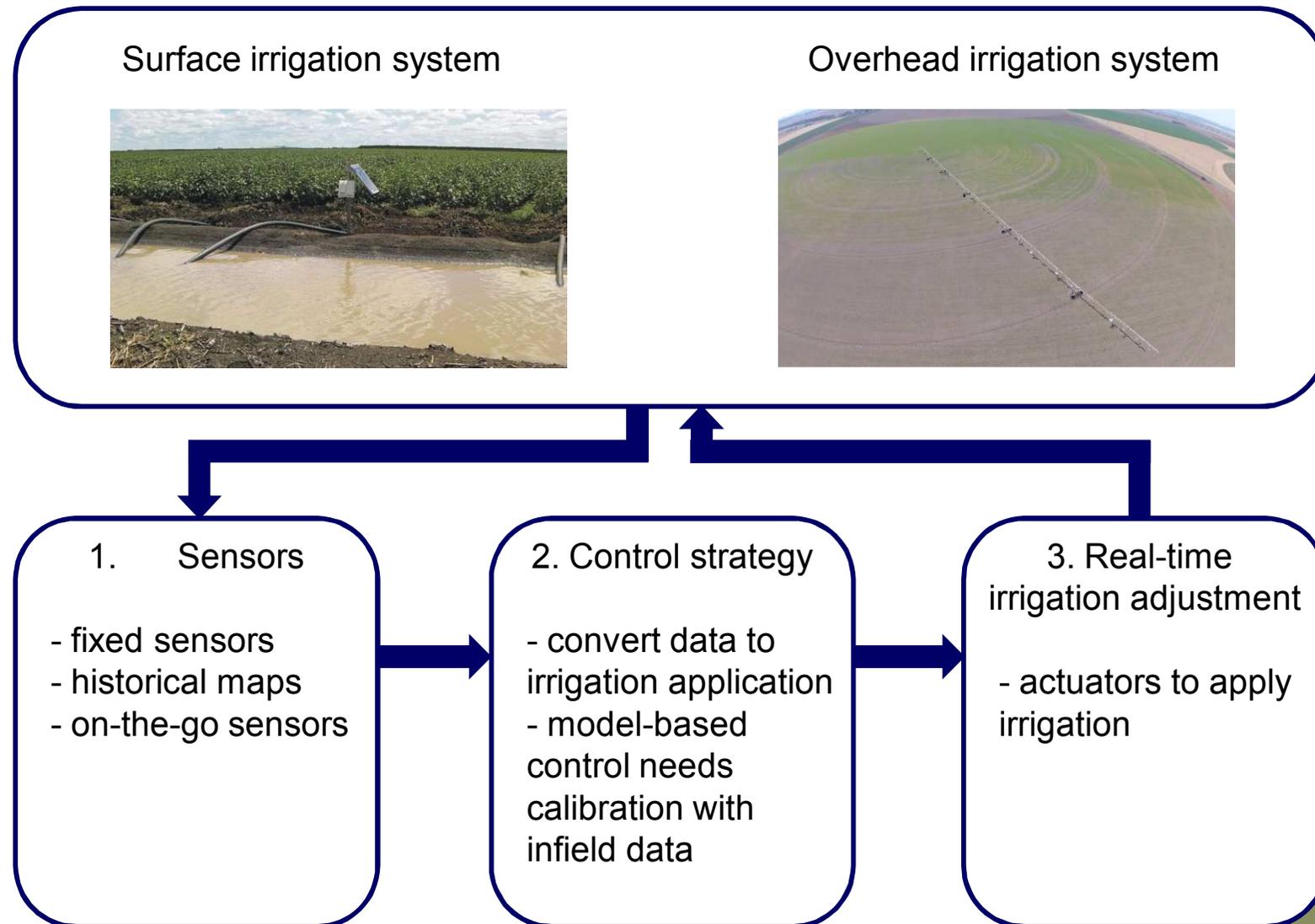
Canopy cover from cameras

0 Height (mm) 250



VRI research

- CPLM VRI is historical map based
- Developing automated control strategies for timing and volume



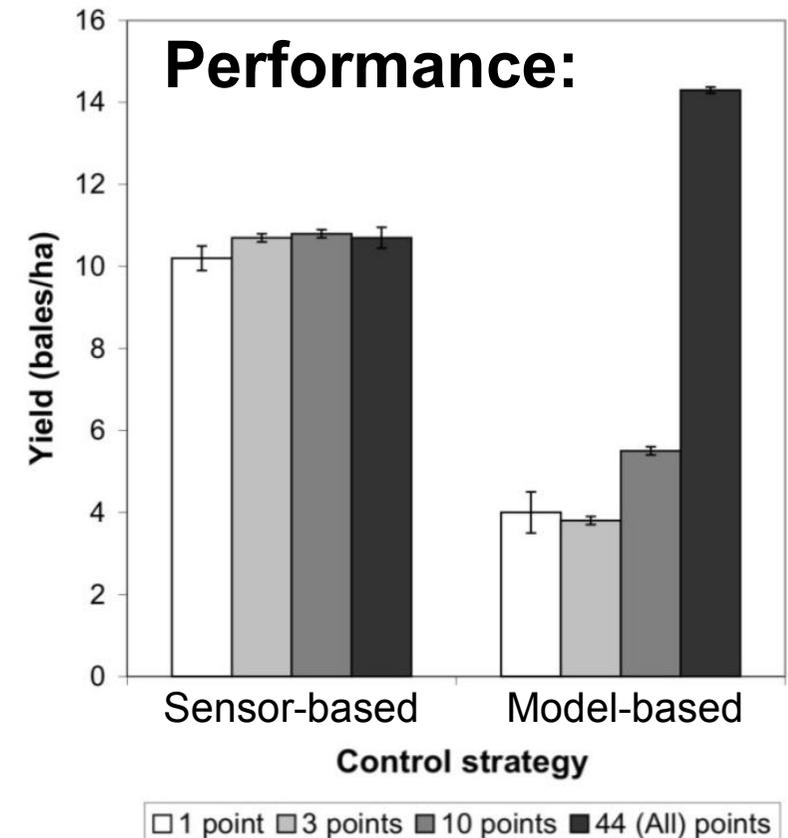
Irrigation control strategies

■ Sensor-based control

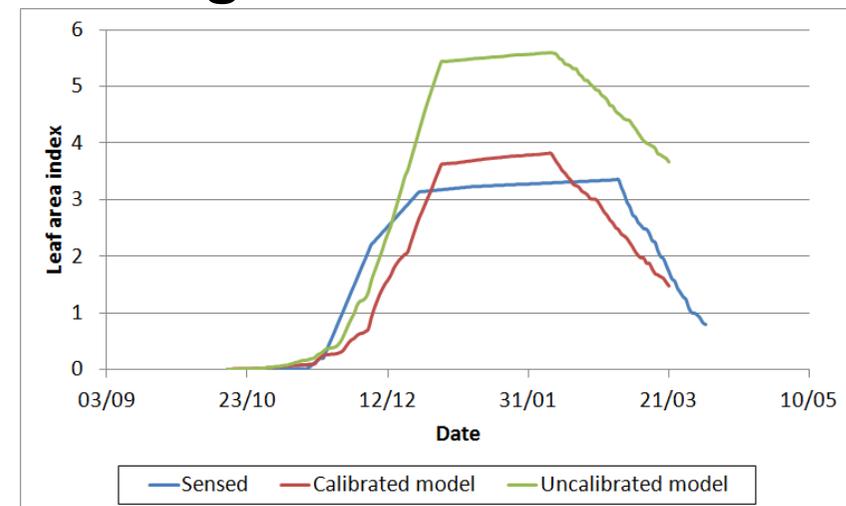
- Soil moisture status estimation using soil, temperature and/or reflectance sensors

■ Model-based control:

- 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
- Potentially higher yields than sensor-based control

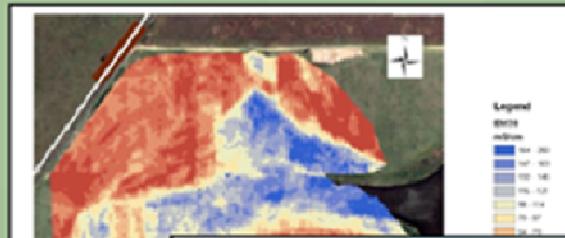


Plant growth calibration:

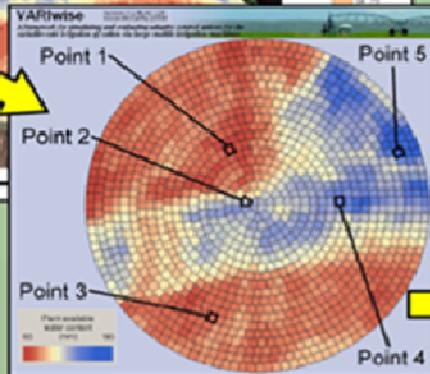


Simulation of sensor-based control

1. EM38 map imported into VARIwise



2. Plant available water content map



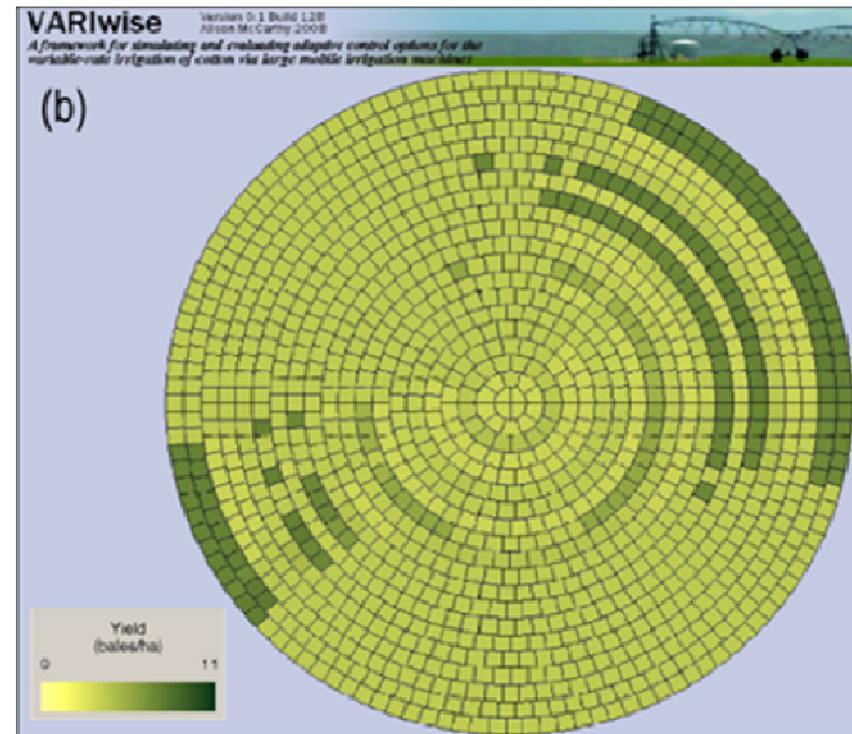
3. Centre pivot uniformity can be imported

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



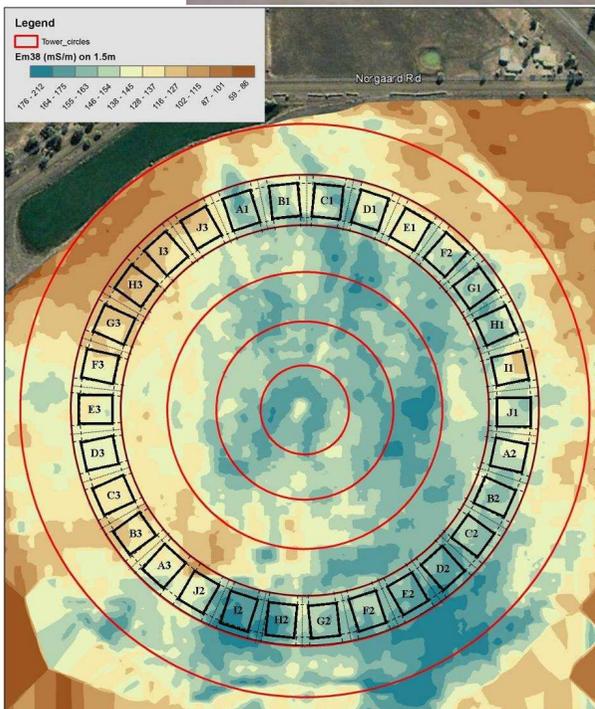
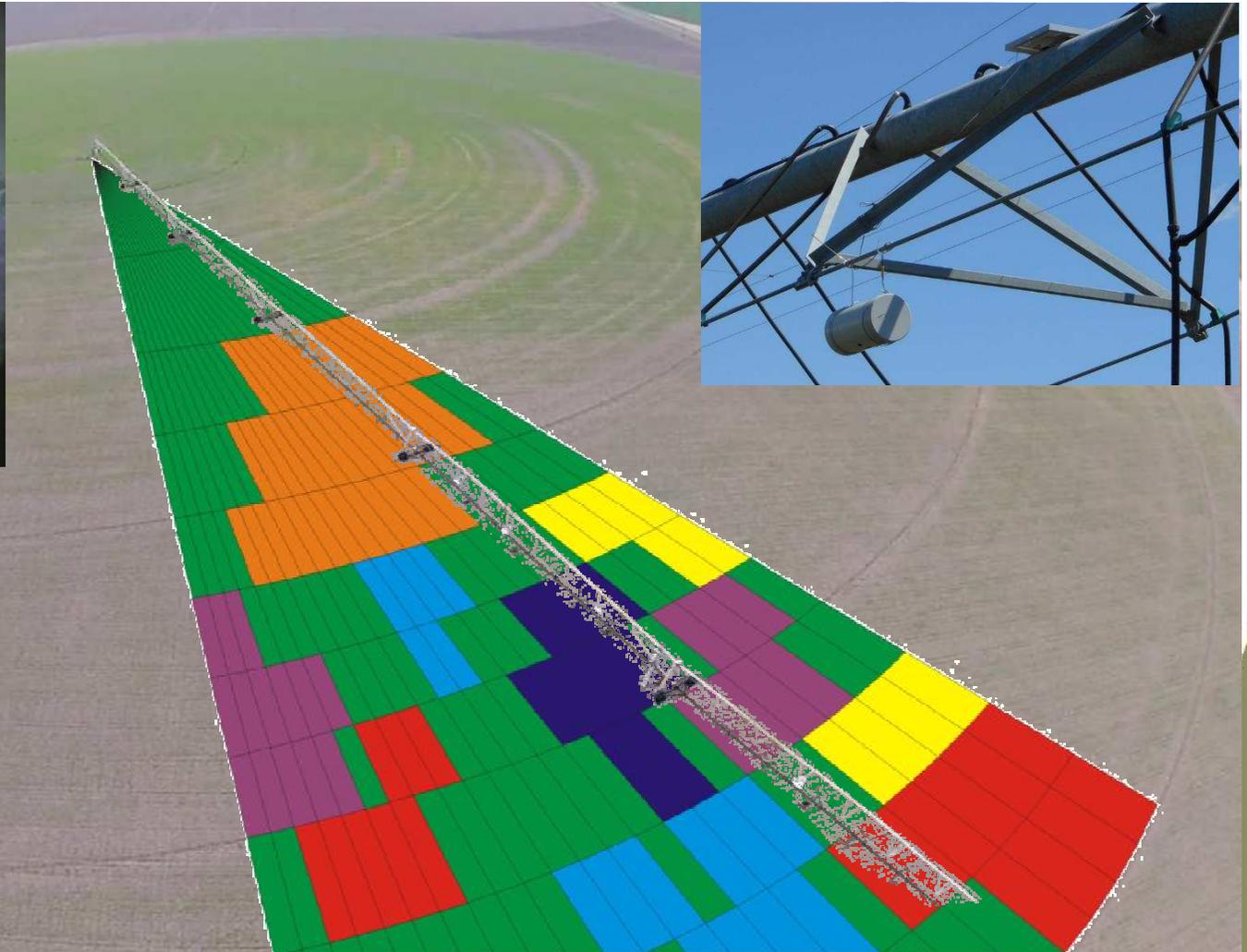
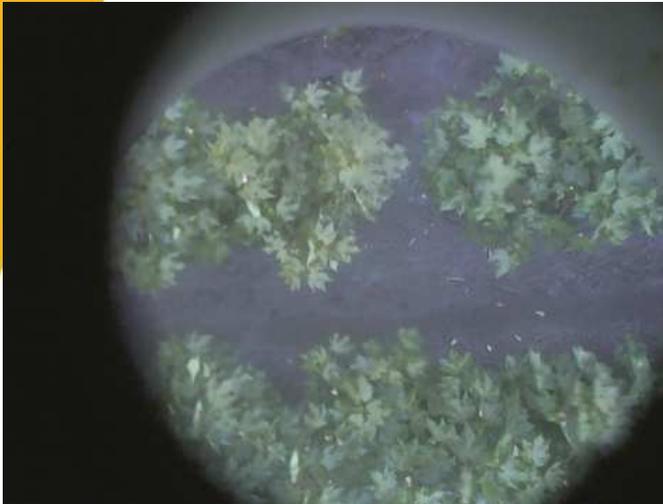
Sensor location	Variability in machine uniformity	Yield (bales/ha)	Irrigation water use efficiency (bales/ML)
Point 1	Low	7.0	0.7
	High	7.0	1.0
Point 2	Low	7.1	0.7
	High	7.0	1.0
Point 3	Low	7.1	0.8
	High	4.6	0.4
Point 4	Low	6.8	0.7
	High	7.0	1.0
Point 5	Low	7.4	0.9
	High	7.0	0.9

Control system implementation on centre pivot



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



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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- Cotton Research and Development Corporation, Federal Government Rural R&D for Profit Program, Queensland Government, TIA, Dairy Australia for funding support
- Growers Ed Windley, and Neil and Lachlan Nass for providing field trial sites