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NCEA
National Centre for Engineering in Agriculture

Improved bean and carrot irrigation using automated site-specific control and sensing

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

Research at USQ

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- **Institute for Agriculture and the Environment**
  - Centre for Crop Health
  - International Centre for Applied Climate Sciences
  - Computational Engineering and Science Research Centre
  - **National Centre for Engineering in Agriculture (NCEA)**
    - Sustainable soils
    - **Irrigation (IWRM)**
    - Energy
    - Precision agriculture
    - **Automation, robotics and machine vision (ARM)**
  - Australian Centre for Sustainable Business and Development
  - Centre for Future Materials
  - Centre for Health Sciences Research
- Institute for Resilient Regions

NCEA-IWRM full-time research staff:
5 agricultural engineers
1 mechatronic engineer
2 electronic engineers
2 software engineers

NCEA-IWRM in 2016-17:
Current projects: 6;
Current students: 4 PhD, 3 Hon.

NCEA-ARM full-time research staff:
5 mechatronic engineers
5 electronic engineers
4 software engineers
2 mechatronic professors

NCEA-ARM in 2016-7:
Current projects: 7;
Current students: 6 PhD, 3 Hon.;
CASA-approved Remote Pilots: 2

Need for precision in farming inputs

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:

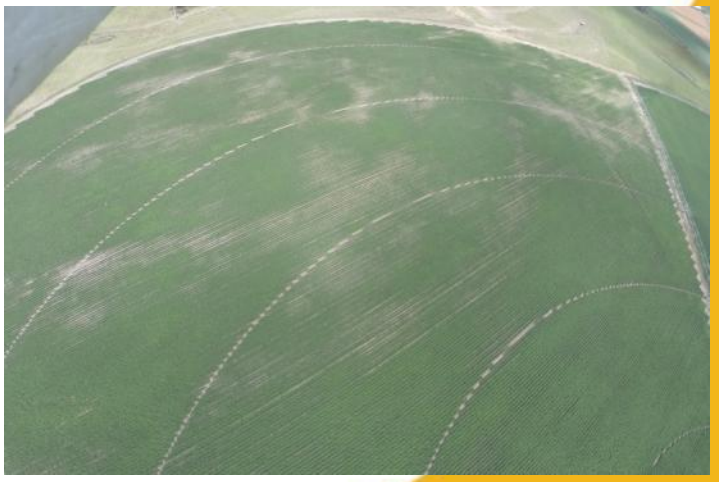
Horticulture field in Kalbar:

VRI hardware

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

Commercial VRI use

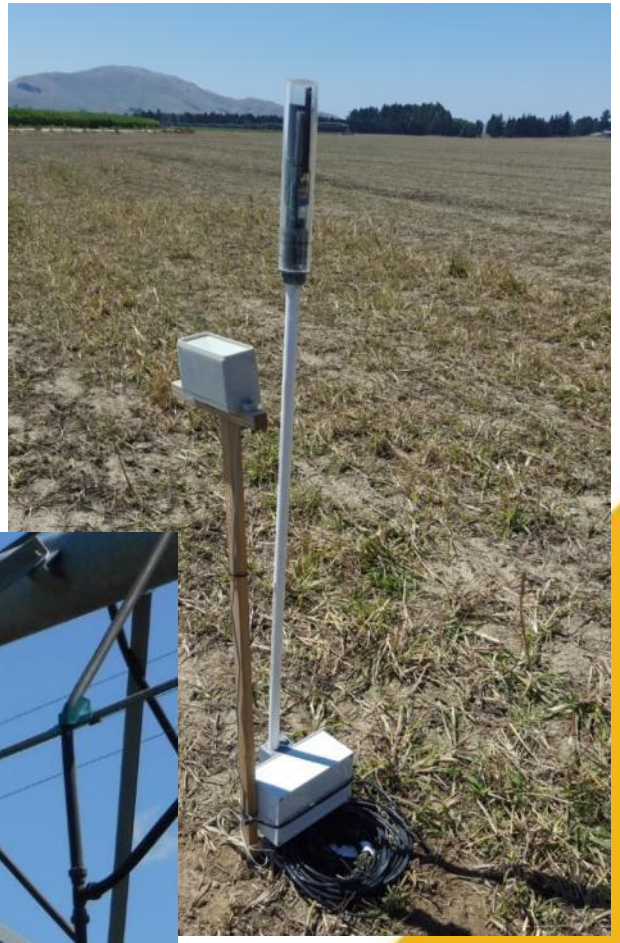
- Cost about $1500/ha – includes VRI hardware, GPS, software, remote access
- Generally 0-20% yield increase or water reduction reported in literature
- Generally used for avoiding roads
- Only 10% of VRI purchased still used



VRI research

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

Soil moisture network in NZ:



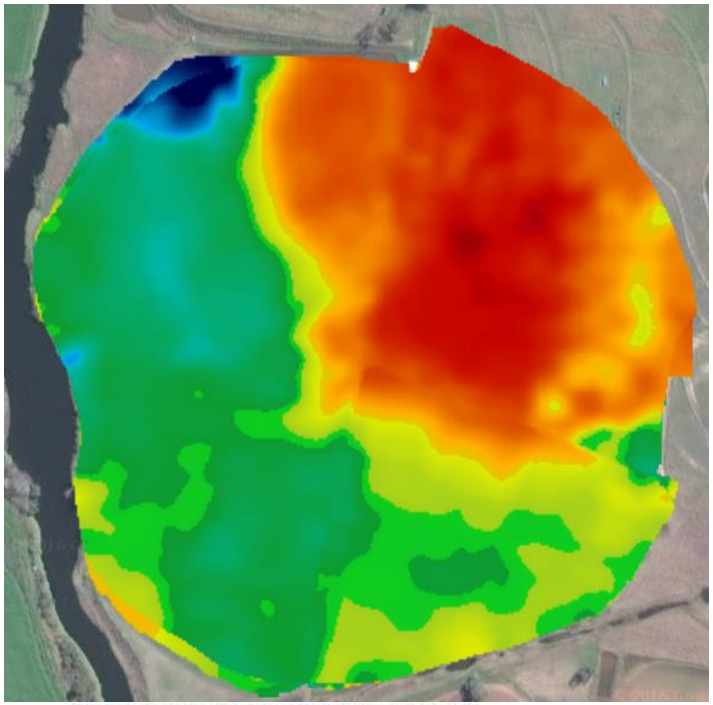
IRTs in Texas:

Cameras in QLD:

Prescription map development

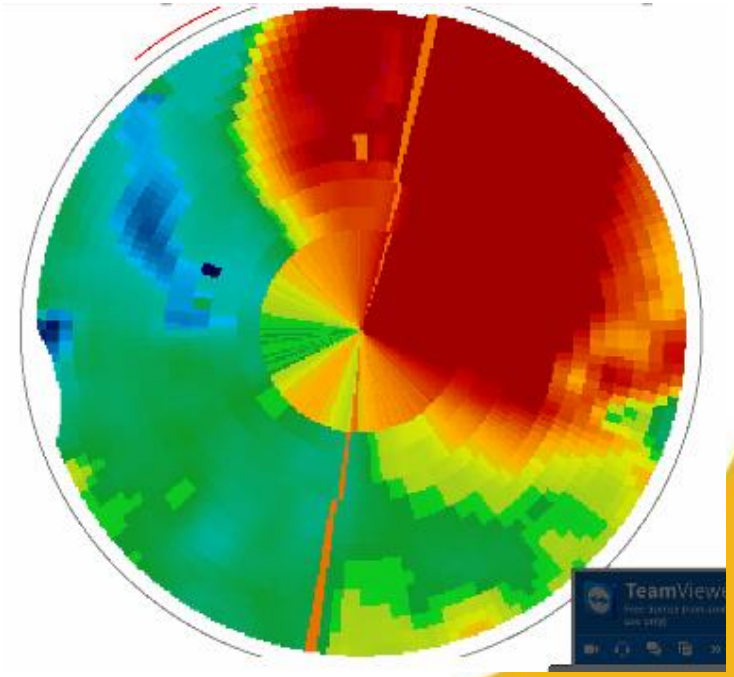
- Centre pivot fields divided into 1° sectors and zones
- Original VRI systems needed manual entry of volumes
- SST/PCT can export data to define zones

Original map:



CRICOS QLD00244B NSW 02225M TEQSA PRF12081

VRI map:



Monitoring soil moisture

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NW_block_vert

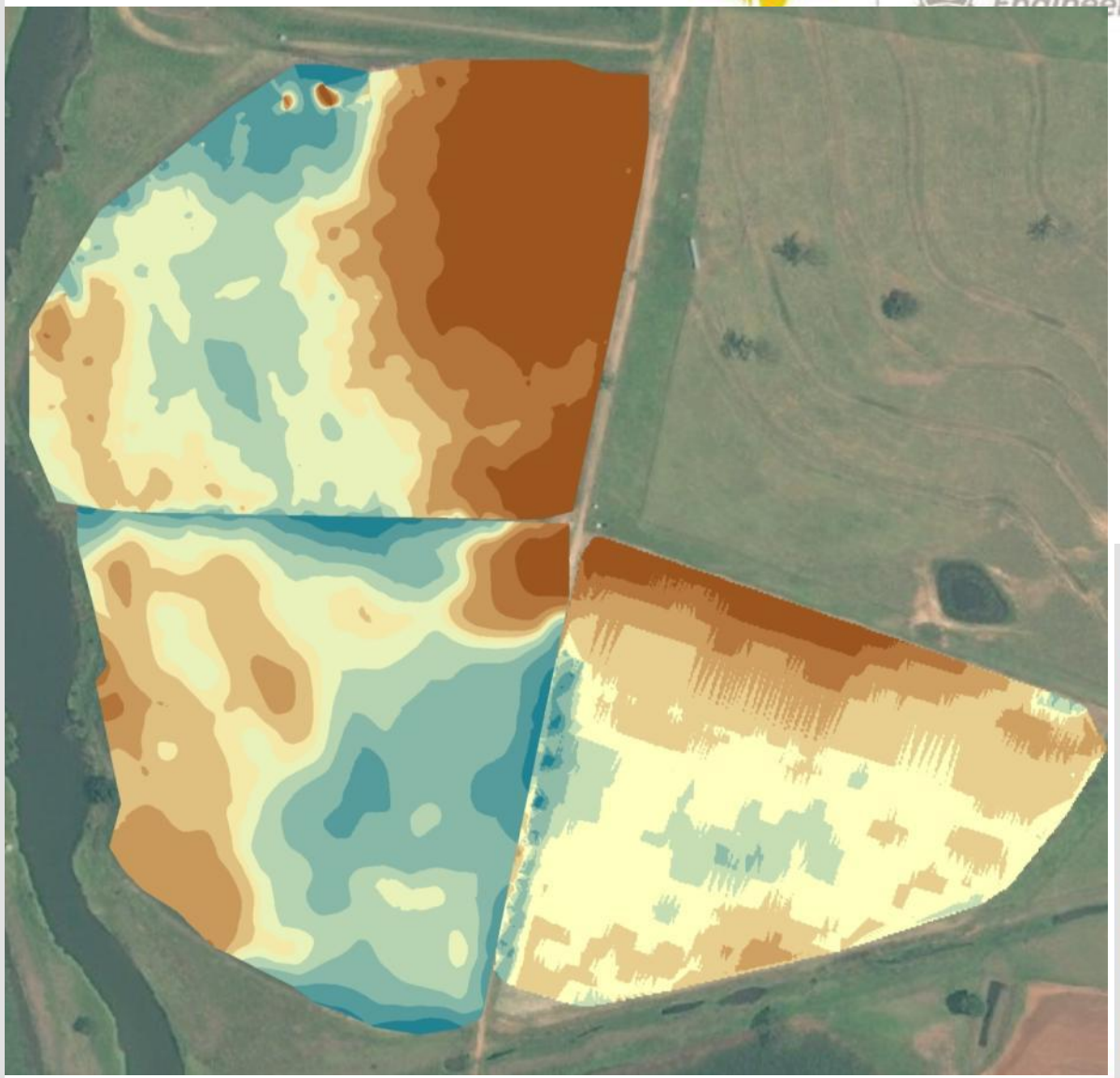
ECa (mS/m)

- 325 - 425
- 264 - 324
- 227 - 263
- 204 - 226
- 191 - 203
- 182 - 190
- 169 - 181
- 146 - 168
- 109 - 145
- 47 - 108

SW_block_vert

ECa (mS/m)

- 194 - 233
- 170 - 193
- 156 - 169
- 148 - 155
- 143 - 147
- 140 - 142
- 135 - 139
- 127 - 134
- 112 - 126
- 88 - 111



5M TEQSA PRF12081

SE_block_vertical

ECa (mS/m)

- 263 - 291
- 242 - 262
- 226 - 241
- 214 - 225
- 197 - 213
- 176 - 196
- 147 - 175
- 108 - 146
- 55 - 107

Monitoring – aerial imagery

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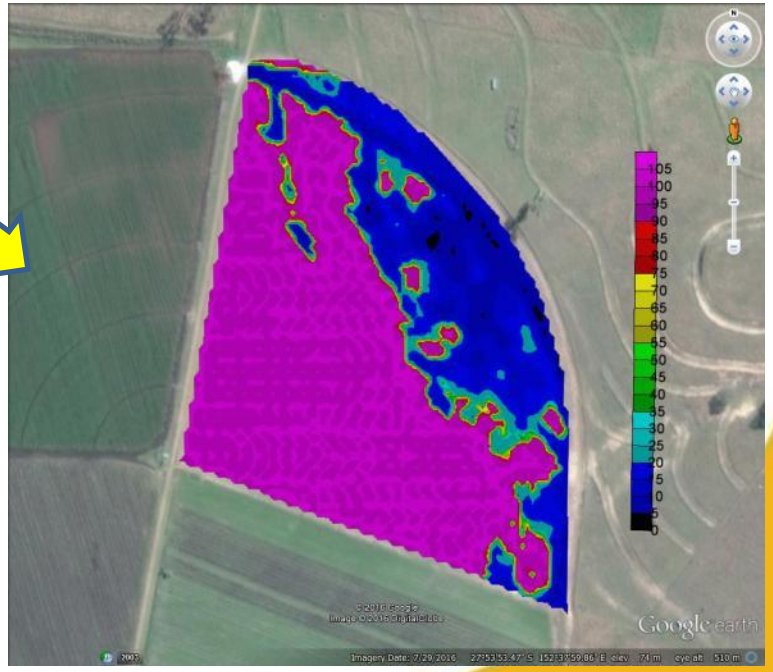
Variability in bean canopy:



Monitoring – machine imagery

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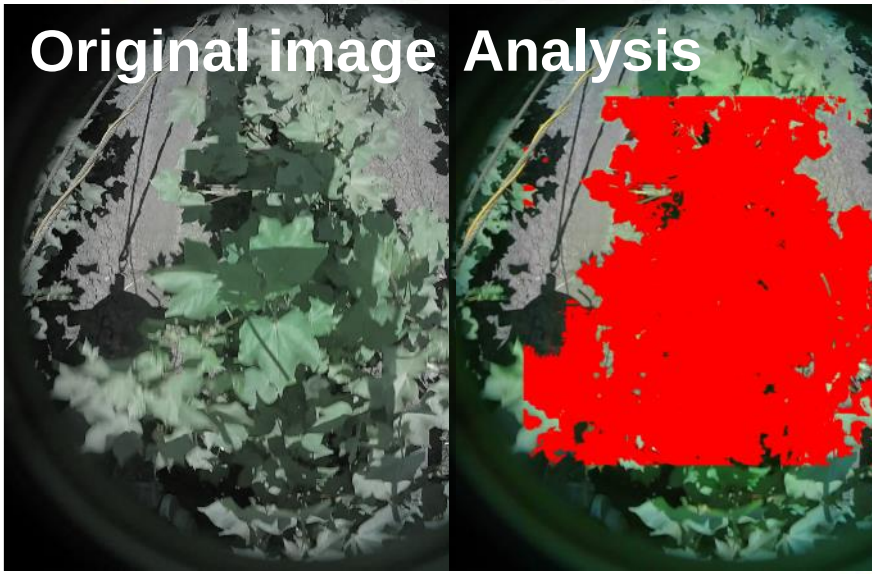
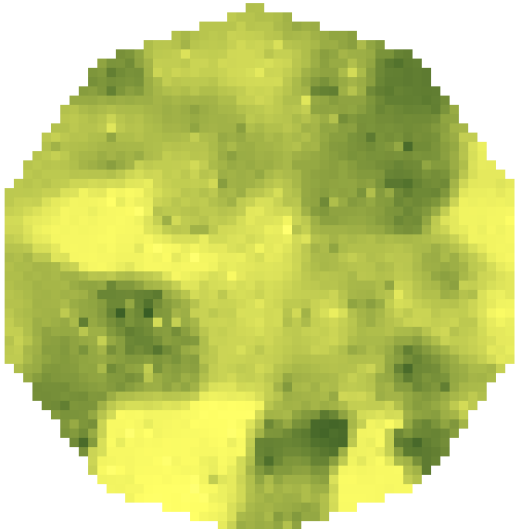
Smartphone camera

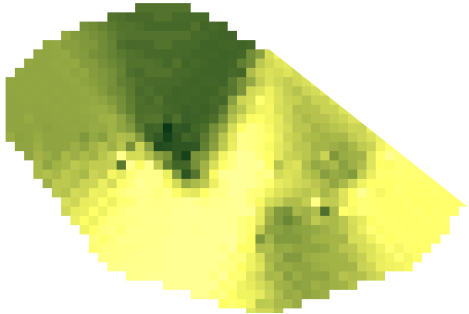


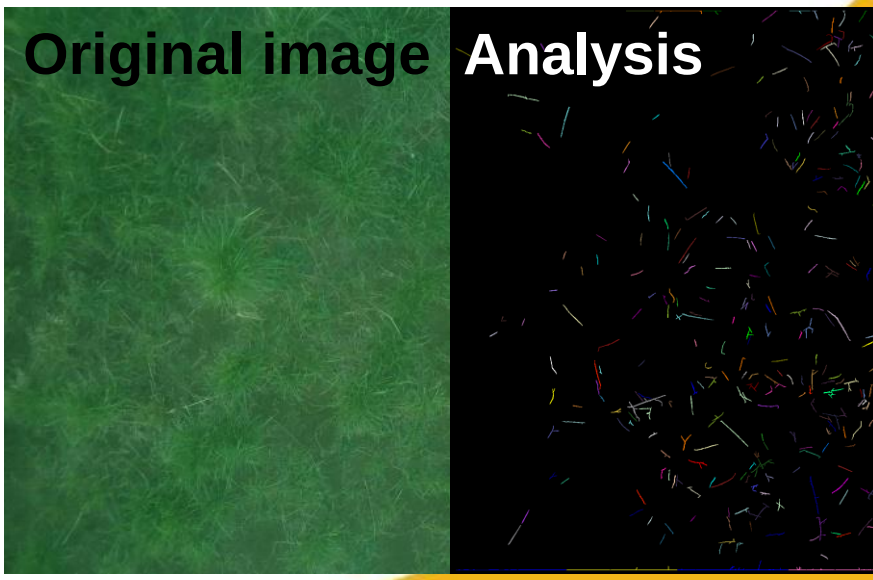
Height from quad bike sensor



Canopy cover from cameras

0 Height (mm) 250





NCEA VRI research

- CPLM VRI is historical map based
- Developing automated control strategies

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

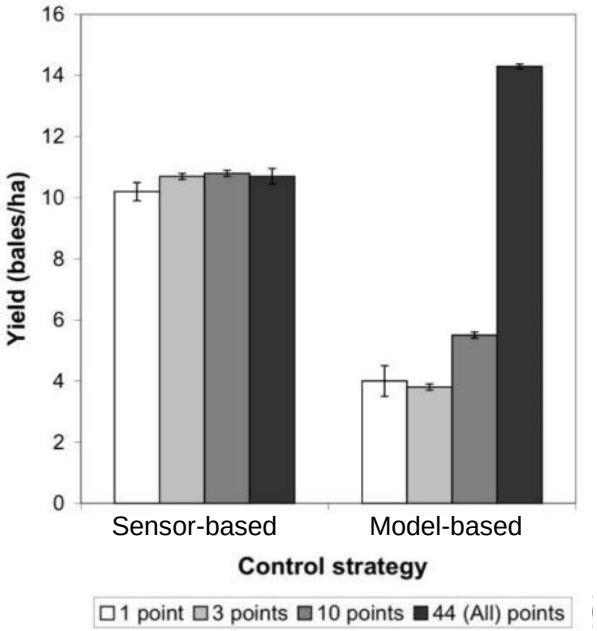
3. Real-time irrigation adjustment

- actuators to apply irrigation

Control system components

- Data input – real-time fixed sensors, historical maps, on-the-go sensors
- Control strategy – algorithms to convert sensor data to irrigation requirement
  - Model-based control needs calibration with infield data
- Actuators – apply irrigation requirement

Model calibration

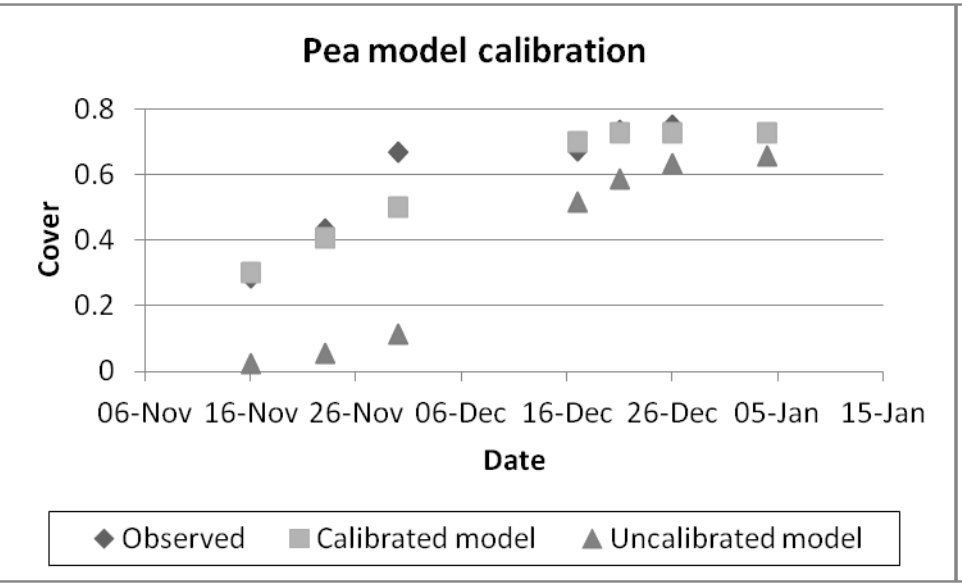


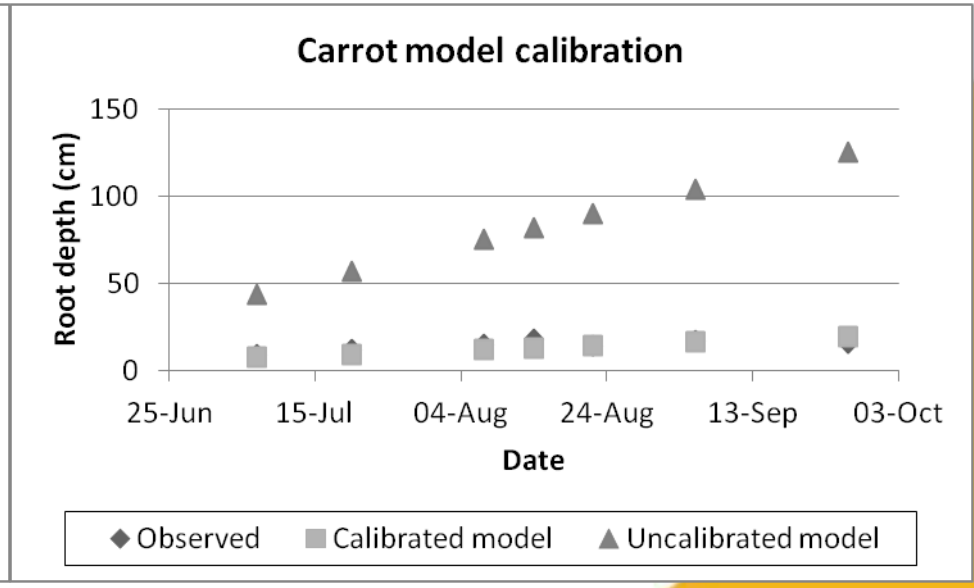
Pulsing solenoids on VRI

Source: Valley

Model calibration

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





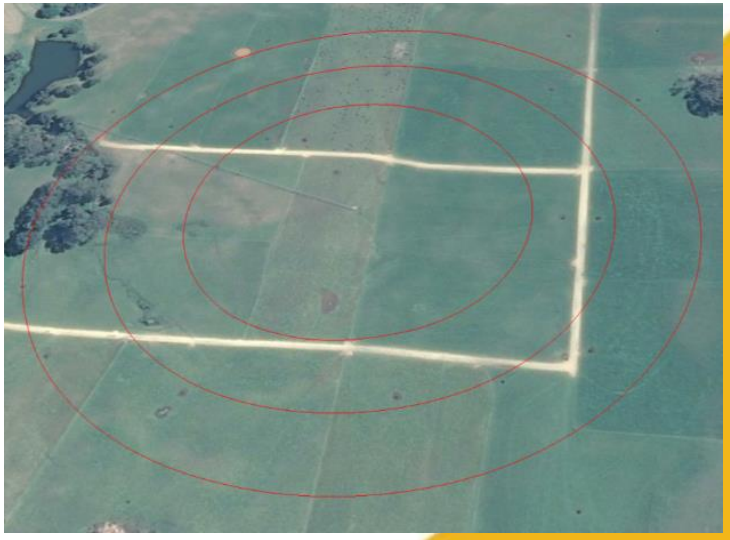
Data pre-processing

- 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



Simulation of sensor-based control

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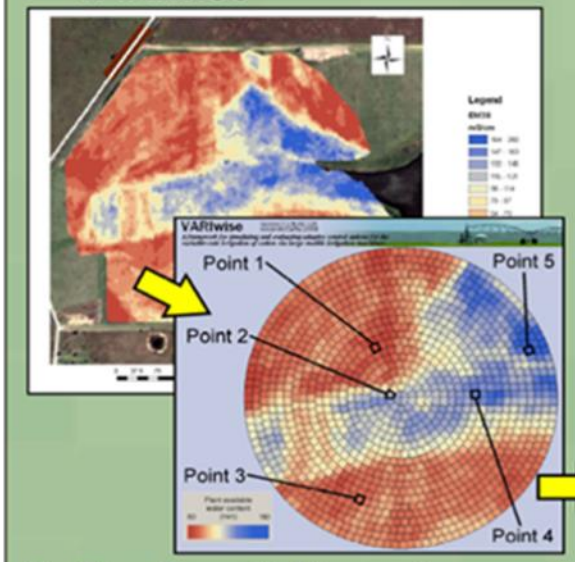
1. EM38 map imported into VARIwise



2. Plant available water content map

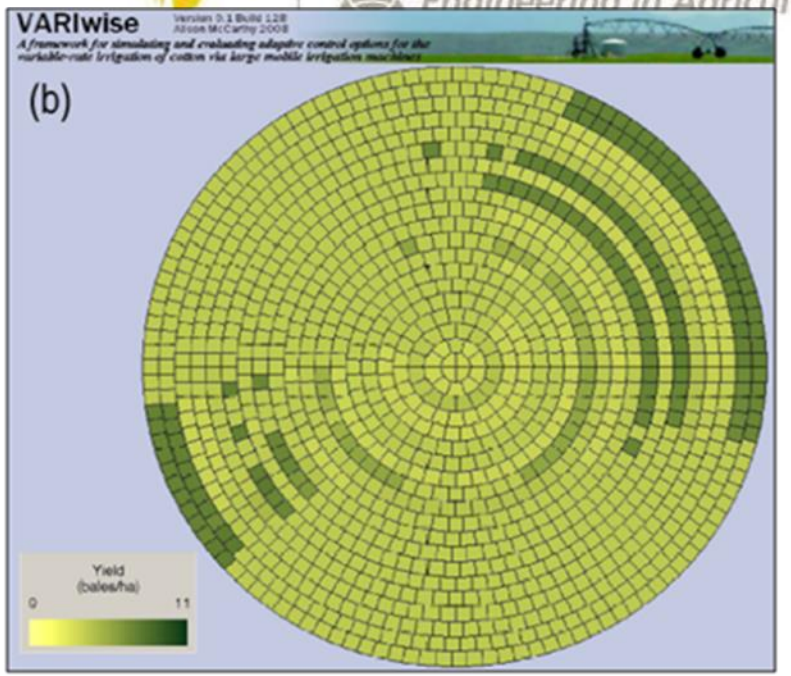
3. Centre pivot uniformity can be imported

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 on centre pivot

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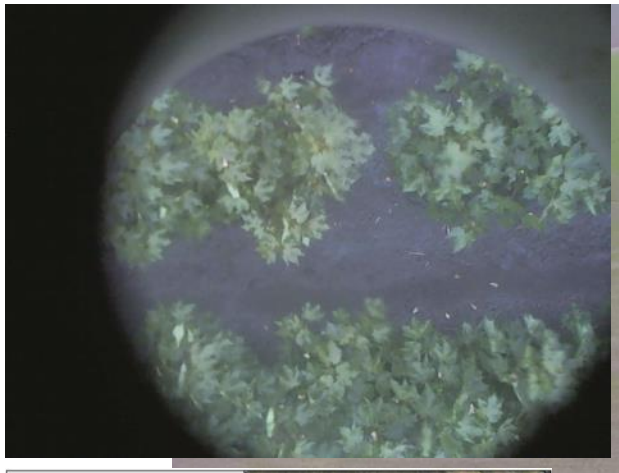
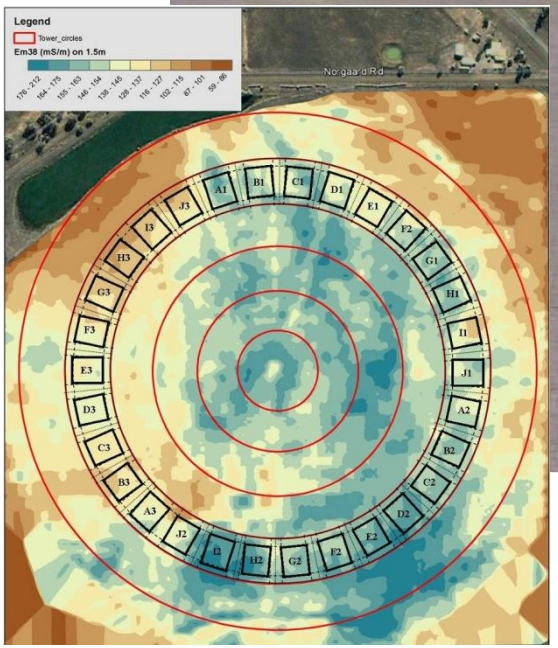
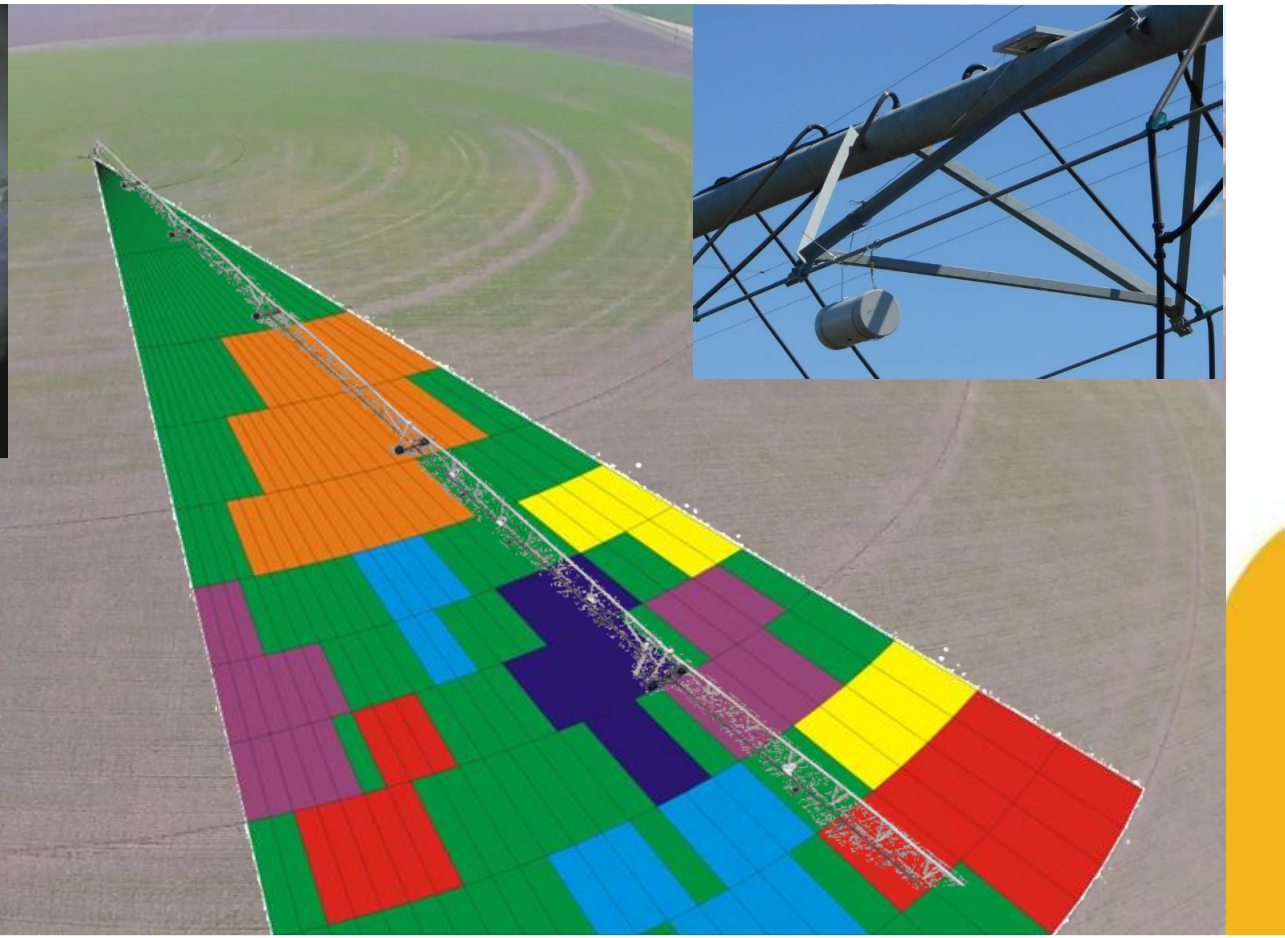
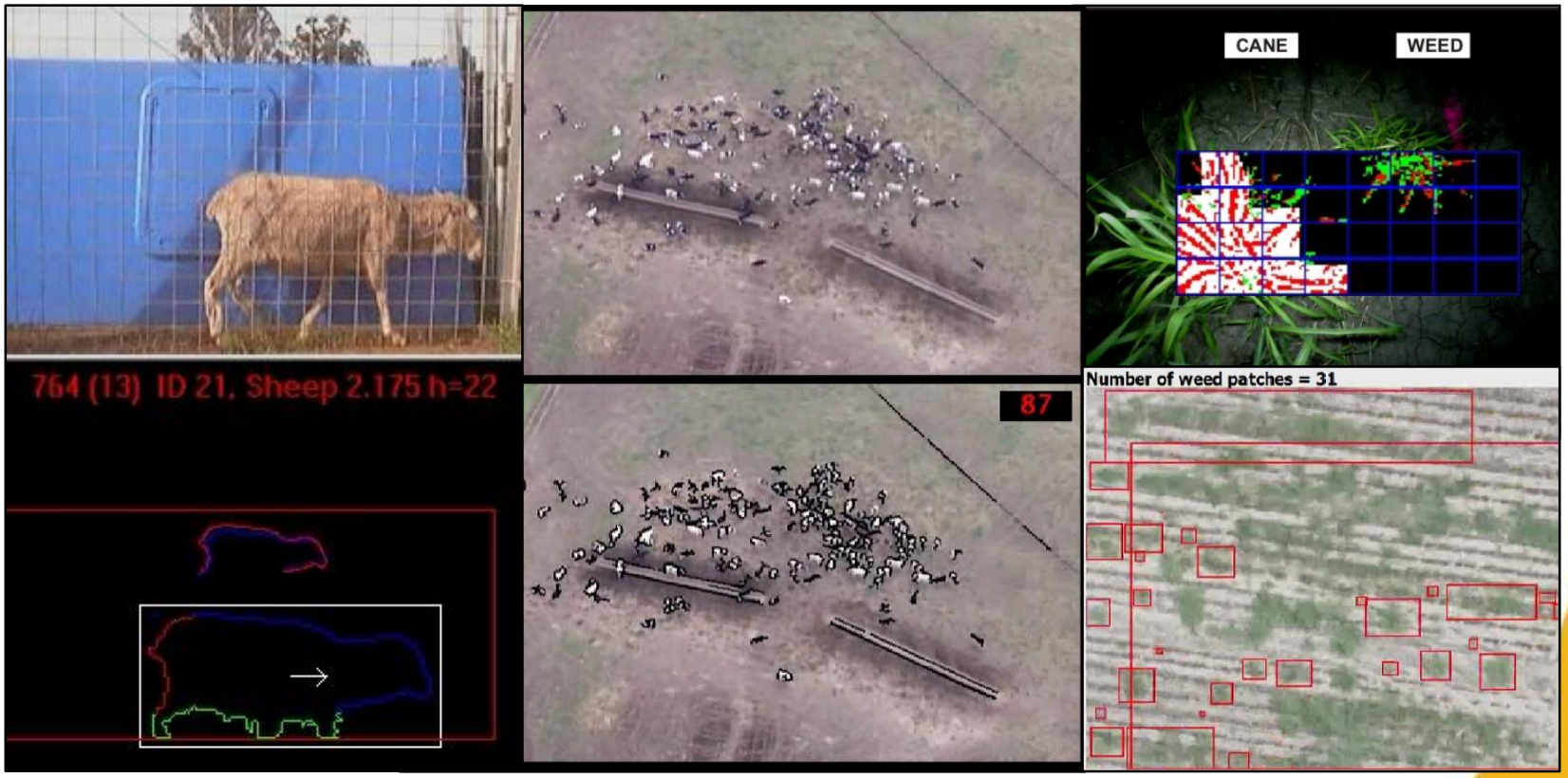
Real-time camera-based plant sensing to update irrigation:





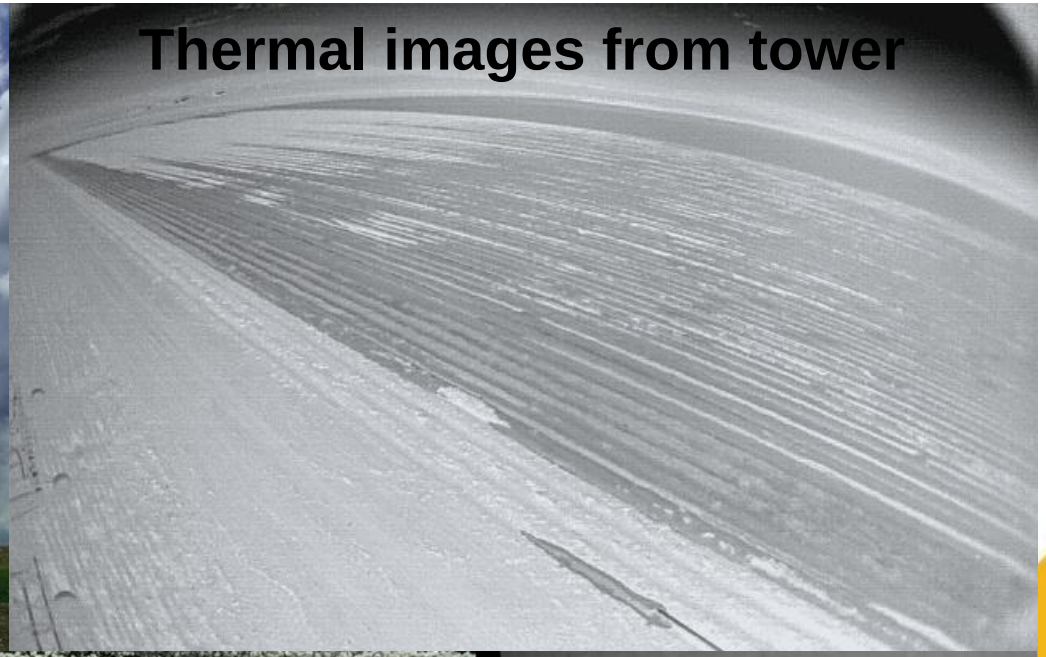


Practical on-farm machine vision systems

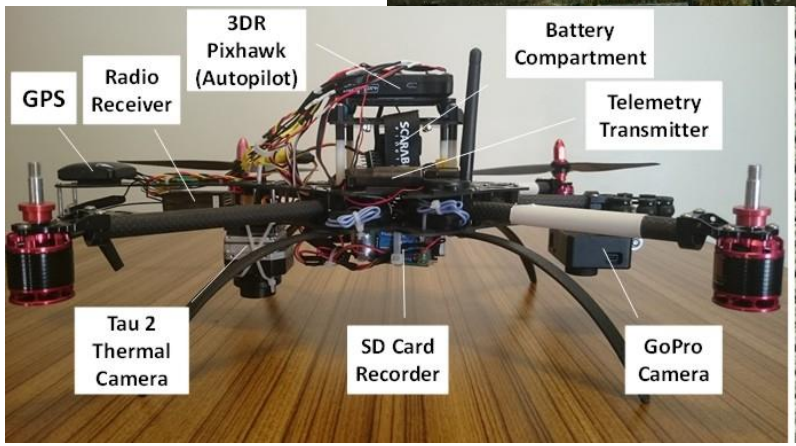


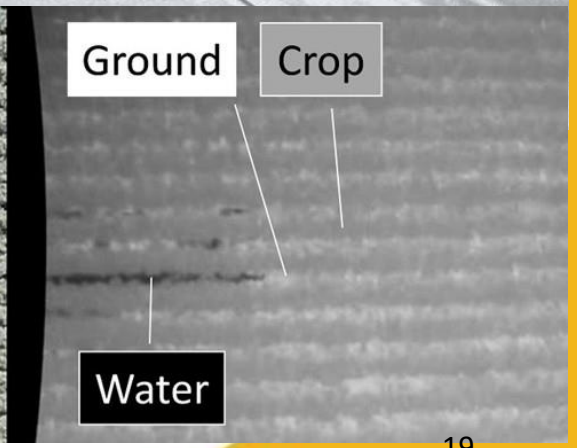
Other machine vision: Irrigation monitoring

Camera tower



Drone





Other machine vision: Remote site monitoring

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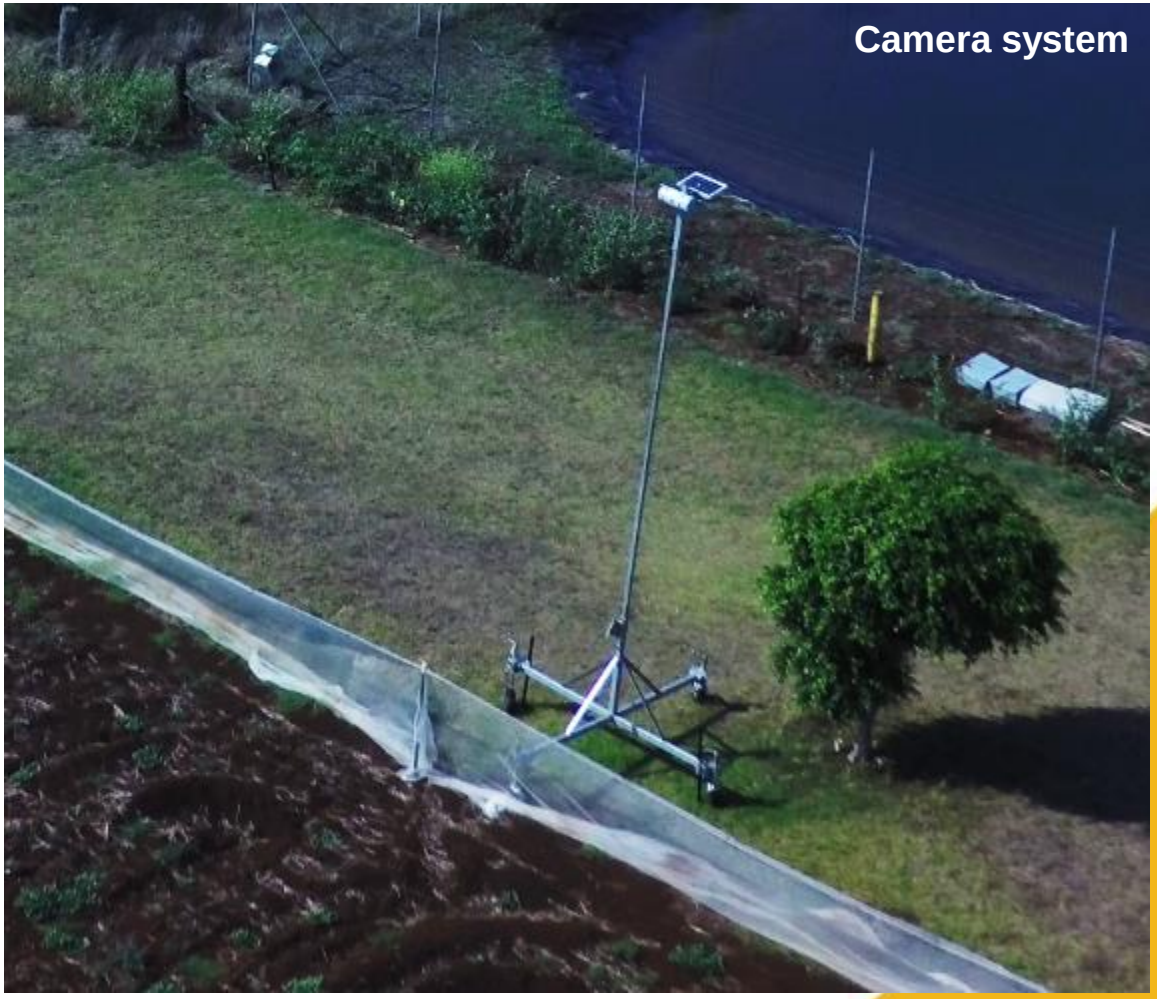
Real-time image analysis can detect shape, colour, height

Wheat variety trial

Wheat flowers

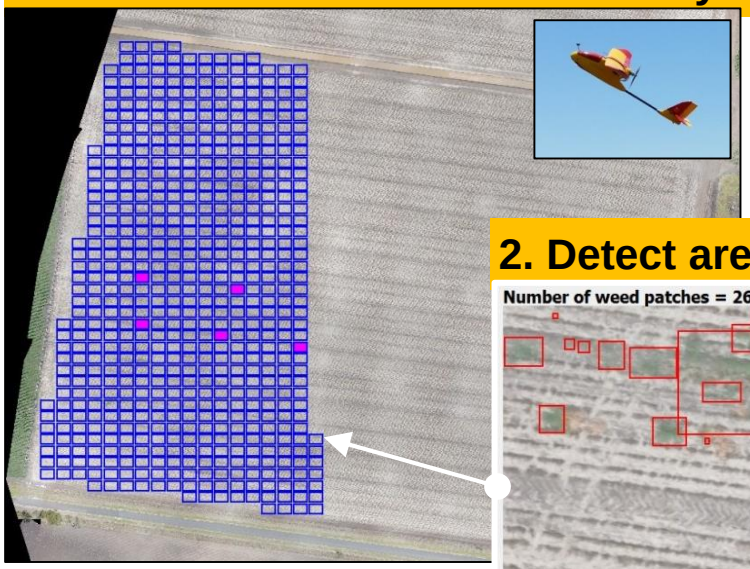


Commercial funding body

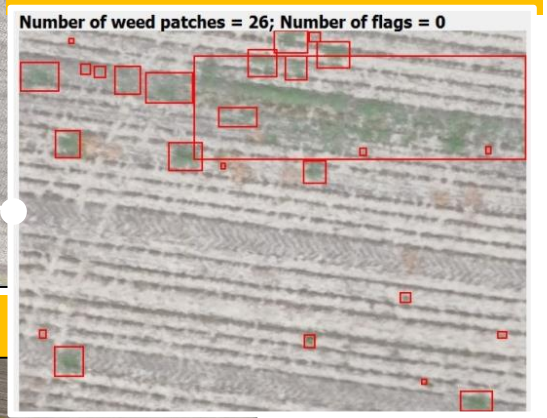
GRDC Grains Research & Development Corporation
Your GRDC working with you

Other machine vision: Weed spot spraying

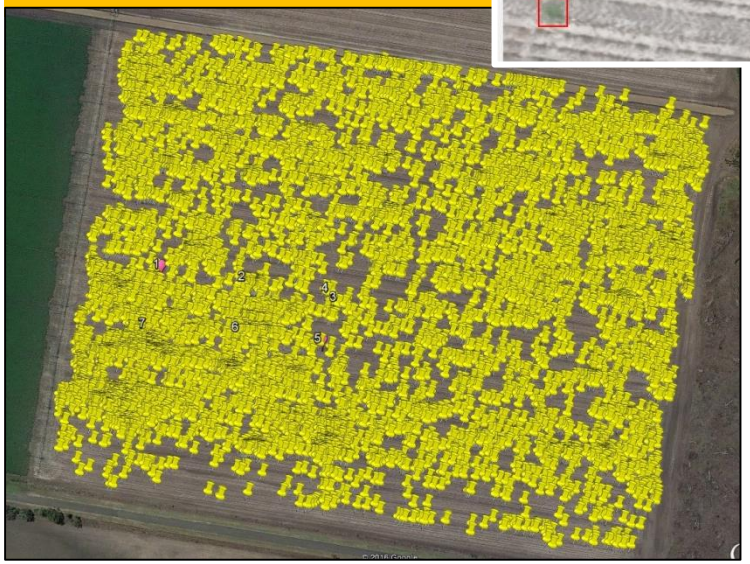
1. Generate orthomosaic and analyse



2. Detect areas of interest



3. Generate KML file



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Aim:

Perform image analysis of drone imagery of a field to automate scouting operations, e.g. look for weeds

Method:

- **Perform flight: 23.5 Ha, 2.34 cm / pixel**
- **Process images into orthomosaic: time 4 hours, 34000 x 31000 pixels**
- **Analyse images: green-from-brown, time 60 seconds**
- **Convert pixel co-ordinates to GPS and create KML (Google Earth) file**

Results:

- **Orthomosaic with <10cm to 10m error**

➢ **Prescription map for spray tractor**

➢ **Extend to weeds in crop, plant size and real-time processing**

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une University of New England

V-TOL AEROSPACE AUTONOMOUS ROBOTIC INTELLIGENCE

Summary

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