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

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Centre for Crop Health
International Centre for Applied Climate Sciences
Computational Engineering and Science Research Centre

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Australian Centre for Sustainable Business and Development
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Automation, robotics and machine vision (ARM)

Sustainable soils
Irrigation (IWRM)
Energy
Precision agriculture

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

IRTs in Texas:  Cameras in QLD:

Soil moisture network in NZ:
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:  
VRI map:
Monitoring soil moisture
Monitoring – aerial imagery

Variability in bean canopy:
Monitoring – machine imagery

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

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

![Graph showing yield comparison between Sensor-based and Model-based control strategies.](image)

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

**Pea model calibration**

**Carrot model calibration**

- Observed
- Calibrated model
- Uncalibrated model
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
Simulation of sensor-based control

1. EM38 map imported into VARlwise
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

<table>
<thead>
<tr>
<th>Sensor location</th>
<th>Variability in machine uniformity</th>
<th>Yield (bales/ha)</th>
<th>Irrigation water use efficiency (bales/ML)</th>
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<td>Low</td>
<td>7.0</td>
<td>0.7</td>
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</table>
Control system on centre pivot

Real-time camera-based plant sensing to update irrigation:
Practical on-farm machine vision systems
Other machine vision: Irrigation monitoring

Thermal images from tower

Camera tower

Drone
Other machine vision: Remote site monitoring

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

Wheat variety trial

Camera system

Wheat flowers

Commercial funding body
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
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