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

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NCEA’s automation research

- 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

Pulsing solenoids on VRI

Rubicon automation hardware

Source: Valley
Site-specific irrigation control 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

Surface irrigation system

Overhead irrigation system

- actuators to apply irrigation

irrigation adjustment

convert data to

fixed sensors
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

<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>Point 1</td>
<td>Low</td>
<td>7.0</td>
<td>0.7</td>
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</table>
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
Before interpolation

On-the-go

Mapped

After interpolation
Image data input

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

Smartphone camera
Image data pre-processing

1. Collect images and location

2. Analyse images

3. Interpolate map

Cover (%)
0 100
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

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

![Graph showing infiltration over distance along furrow](image-url)
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

0 Height (mm) 250

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

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Grain National Variety Trials

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

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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