Camera-based horticulture crop growth monitoring

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Overview

- Background:
  - Need for measurement of infield growth and maturity variability
  - Data collection is labour-intensive
- Development of automated machine vision system for peas and carrots
  - Parameters selected based model calibration and decision
- Evaluation at sites in Queensland and NZ
- Cost benefit analysis of site-specific irrigation

Growth and maturity variability

- Can lead to suboptimal yield, and water and fertiliser use
- Monitoring can be inform management, e.g. site-specific irrigation or fertiliser application
- But this monitoring is labour-intensive

Variability in horticulture field:

Machine vision system – camera

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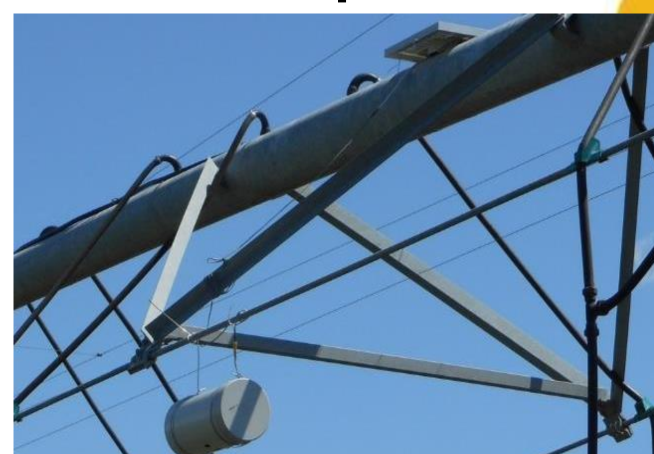
- Smartphone camera
- App on phone capture images
- Image processing on server
- Which parameters to monitor?

System components:

Trial site with cameras along span:

Camera on pivot:



Measurement selection

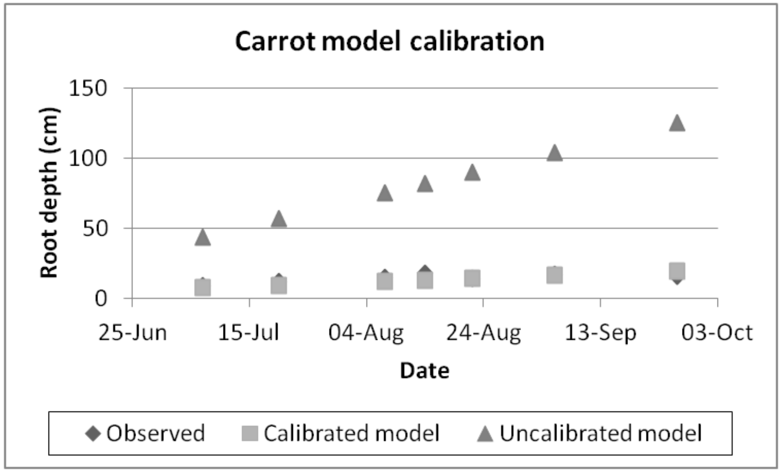
- Link data with crop models for optimisation
- Cover and fruiting for calibrating APSIM model:

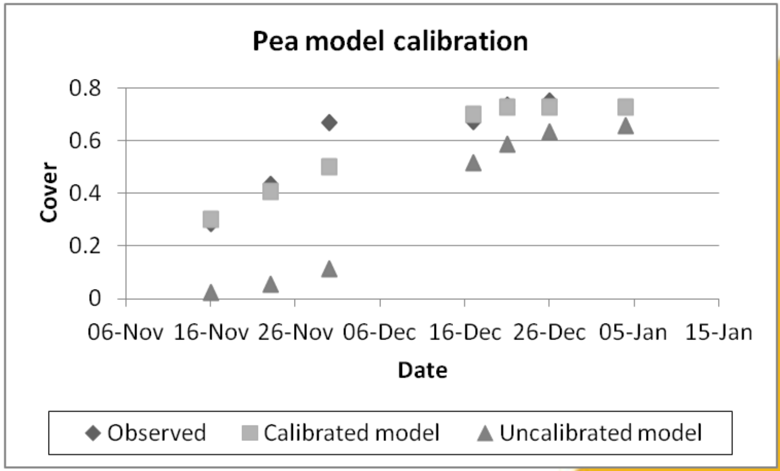
  Carrots

  - Root depth: 54.9 cm to 2.7 cm
  - Root mass: 13.8 g to 10.7 g

  Peas

  - Cover: 8.1% to 2.8%
  - Height: 11.4 cm to 3.5 cm
  - Nodes: 8.1 nodes to 2.8 nodes



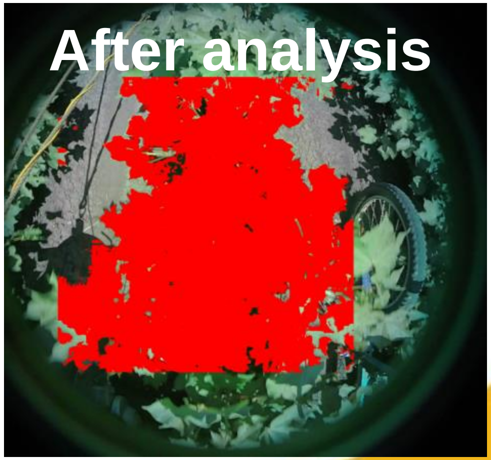


Machine vision system – software

- Automated cover and flower counts for peas
- Automated cover for carrots

Pea crop image analysis:

Canopy cover image analysis:



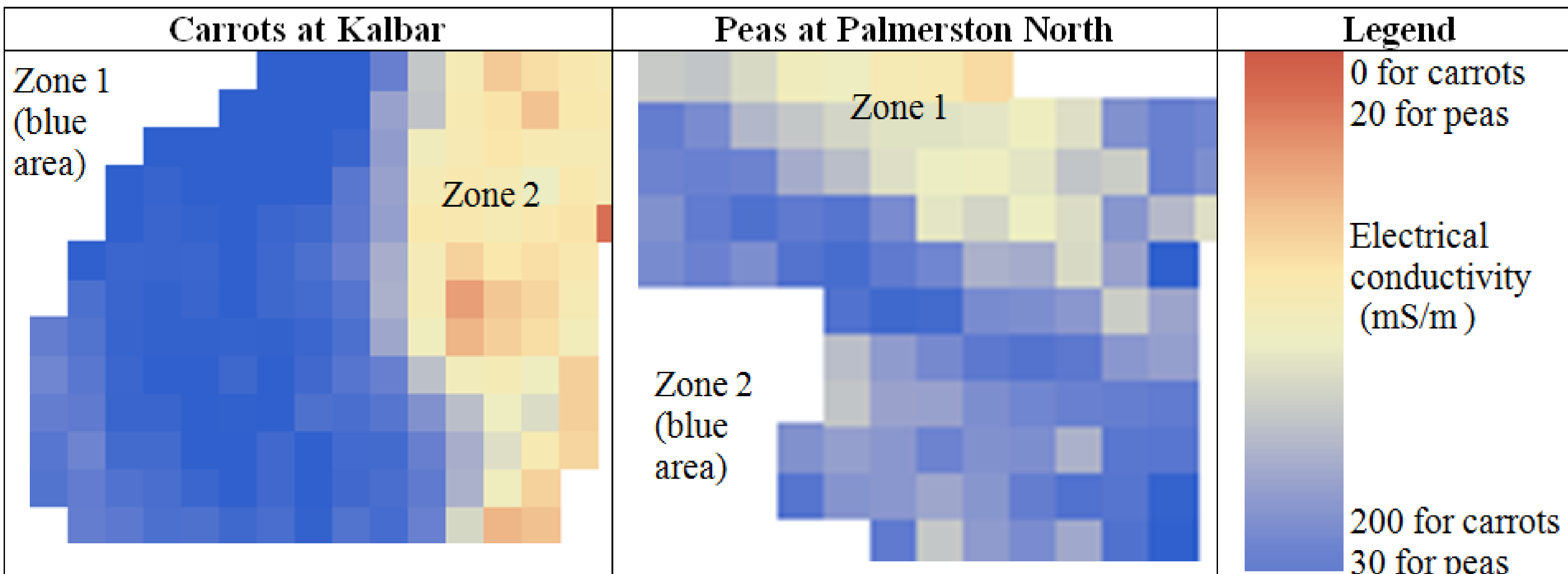
Machine vision system evaluation

1. Select field sites
2. Collect imagery and ground truthing data
3. Image analysis
4. Develop crop maps
5. Cost benefit analysis for use in irrigation optimisation

1. Field site selection

- Two field sites selected for soil, plant growth and fruiting data collection

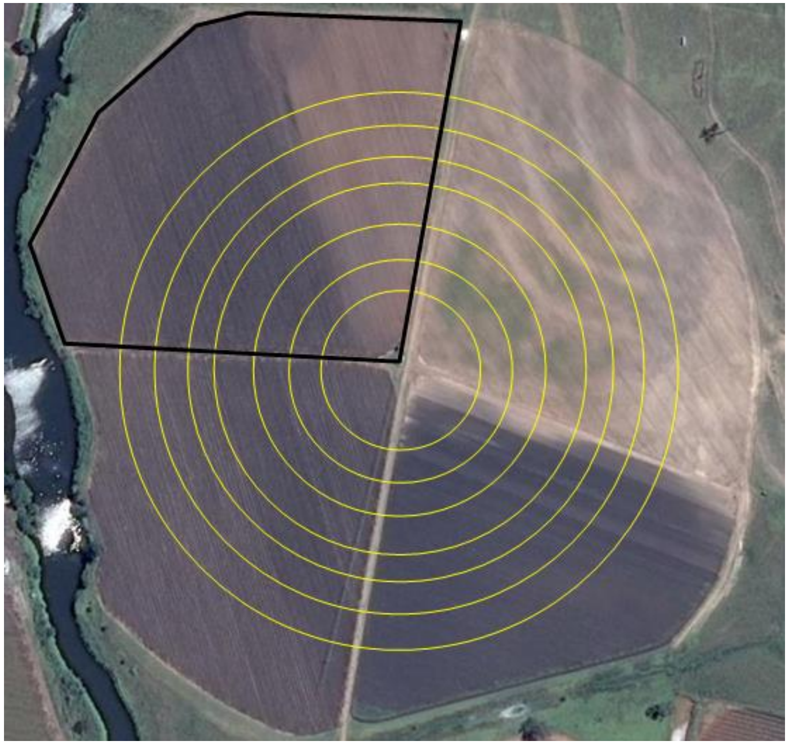
Location	Crop	Season	Cameras along machine (m)	Data collection days
Kalbar	Carrots	30 May 2015 - 26 Oct 2015	80, 106, 125, 165, 180, 210, 225	7/7, 20/7, 7/8, 14/8, 22/8, 5/9, 26/9, 2/10, 10/10
Palmerston North	Peas (Ashton, Massey)	18 Oct 2016 - 9 Jan 2017	52, 56	16/11, 23/11, 30/11, 7/12, 17/12, 21/12, 26/12, 4/1



2. Imagery and data collection

- Weekly ground truthing data
- Weekly dry pivot runs for image collection

Kalbar camera positions:



NZ camera positions:

3. Image analysis

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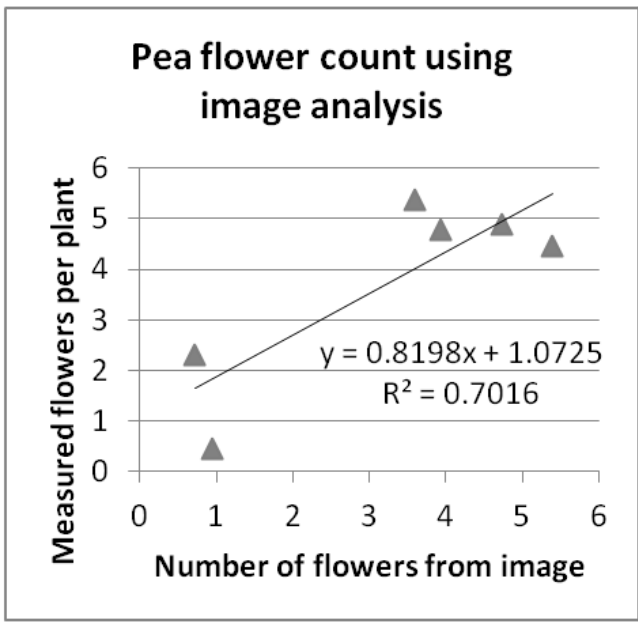
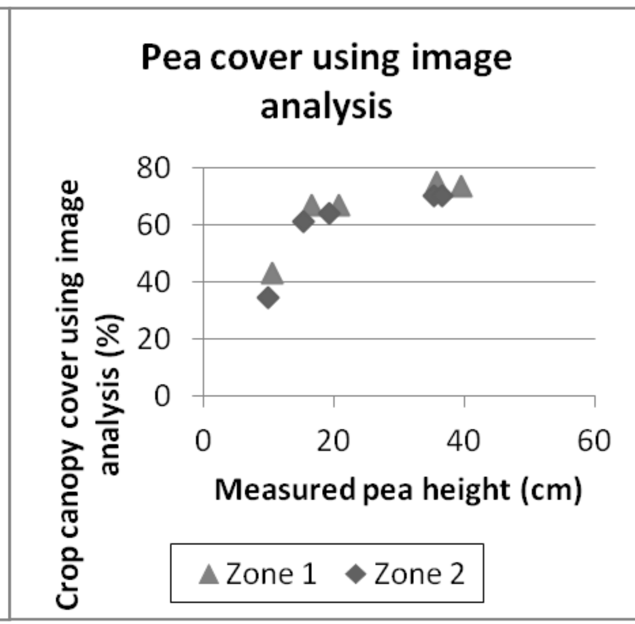
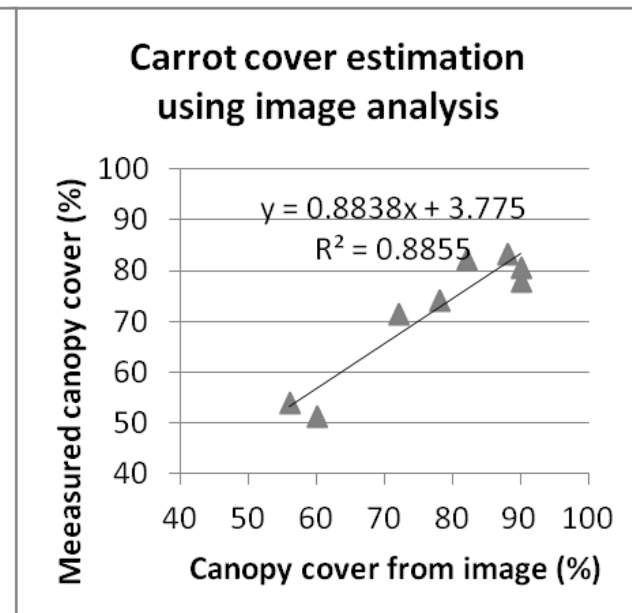
- Flower count error = 0.6 flower/plant
- Carrot canopy cover error = 3.7%
- Higher pea cover error because of flowers



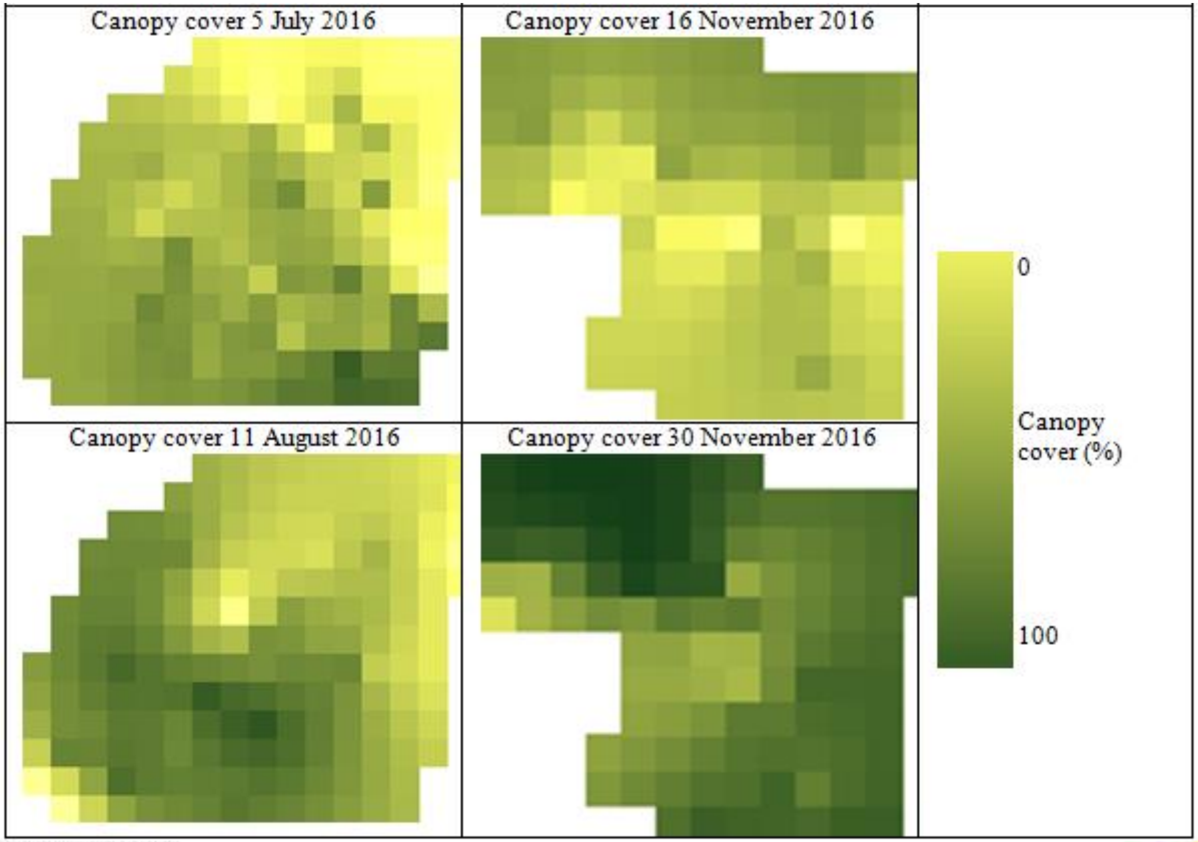




4. Crop mapping

- Convert all data layers to spatial grid
- Kriging to assign value to each cell within field

Interpolated variability maps:



5. Cost benefit analysis: 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
- sensor-based control directly uses sensor data
- model-based control needs calibration with infield data

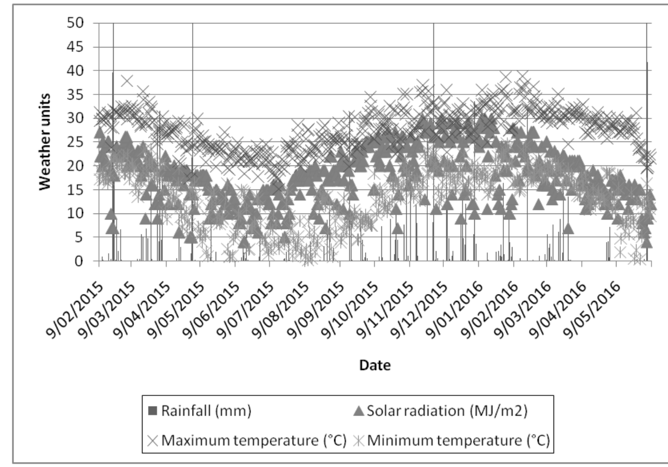
3. Real-time irrigation adjustment

- actuators to apply irrigation

5. Cost benefit analysis: irrigation control system

Variable-rate irrigation hardware:

Weather station:



Control strategy comparisons:

Season	Treatment	Yield (t/ha)	Irrigation applied (ML/ha)
Peas 2016/17	Grower's treatment	3.5	0.0
	Soil-water deficit	3.6	0.6
	Model-based control	3.6	0.3
Peas 2015/16	Soil-water deficit	2.0	0.8
	Model-based control	2.1	0.7
Carrots 2016	Grower's treatment	31.2	0.6
	Soil-water deficit	33.4	0.6
	Model-based control	34.3	0.6

Soil moisture sensors:

5. Cost benefit analysis

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- Payback 4 years:
  - Yield increase 9% ($263/ha)
  - Water reduction 0.7 ML/ha and water price $90/ML
  - Weekly labour reduction 0.5 days
- VRI largest expense, $1500/year increases payback to 8.8 years
- Largest savings from labour reduction

	Cost for variable-rate irrigation ($/ha)
Capital cost	
VRI hardware	500
Electrical conductivity mapping	27
Soil moisture monitoring	184
Plant monitoring	40
Total capital cost per hectare	751
Variable costs	
Data communication	14
Equipment maintenance	50
Total annual operating cost per hectare	64
Return	
Yield improvement	24
Water saving	67
Labour reduction	177
Annual gain	268
Payback period (years)	3.7

Conclusions

- Machine vision system developed for carrot and pea crop monitoring
- Image analysis estimate flowers to 0.6 flower/plant
- Carrot canopy error was 3.7%
- Potential for use in variable-rate irrigation or fertigation control system
- VRI payback period 4 years
- Further work – evaluation of the control strategies

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