Australian Government

Cotton Research and Development Corporation

NCEA

Development of a sensing system for automated cotton fruit load and vegetation estimation

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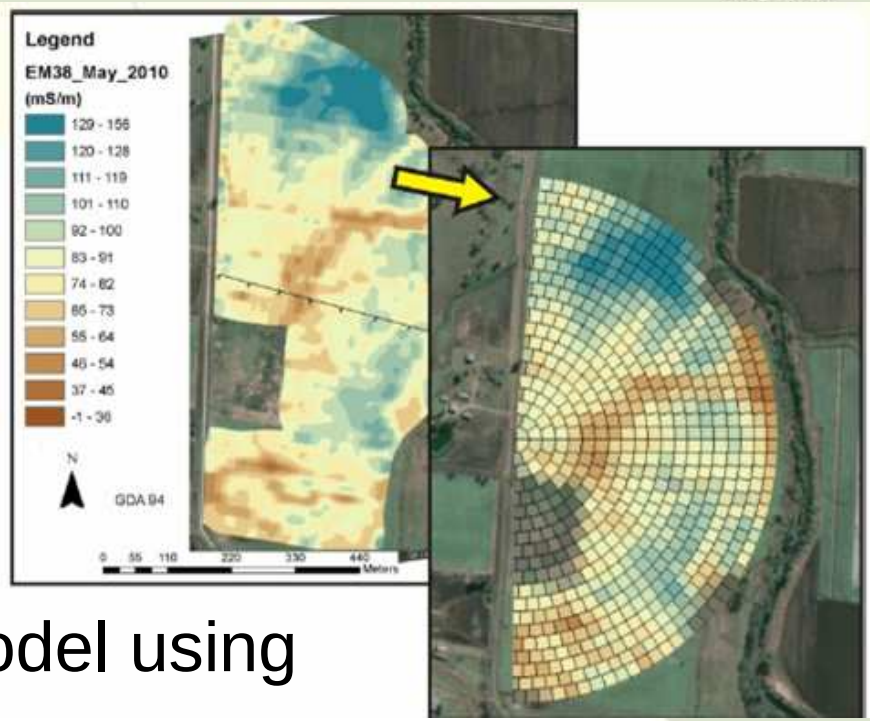
VARIwise control framework

- VARIwise:
  simulates and develops site-specific irrigation control strategies



- Steps for model-based strategies:
  1. Calibrate crop production model using input soil/plant parameters
  2. Repeatedly execute model with different irrigation volumes and timing to determine irrigation that produces the desired performance objective
- Plant parameters required to calibrate model:
  leaf area index, square count, boll count and plant density

Cotton plant sensing

- Plant condition from visual attributes
  - vegetative growth, leaf area, flowering timeframe, boll capacity, plant density
- Plant density influences micro-climate
  - soil moisture extraction, light interception, humidity and wind movement

  ...which also influences:
  - plant height, branch development, fruit location and size
- Beneficial to automated irrigation control systems

Sensing systems for field crops

Commercially-available:

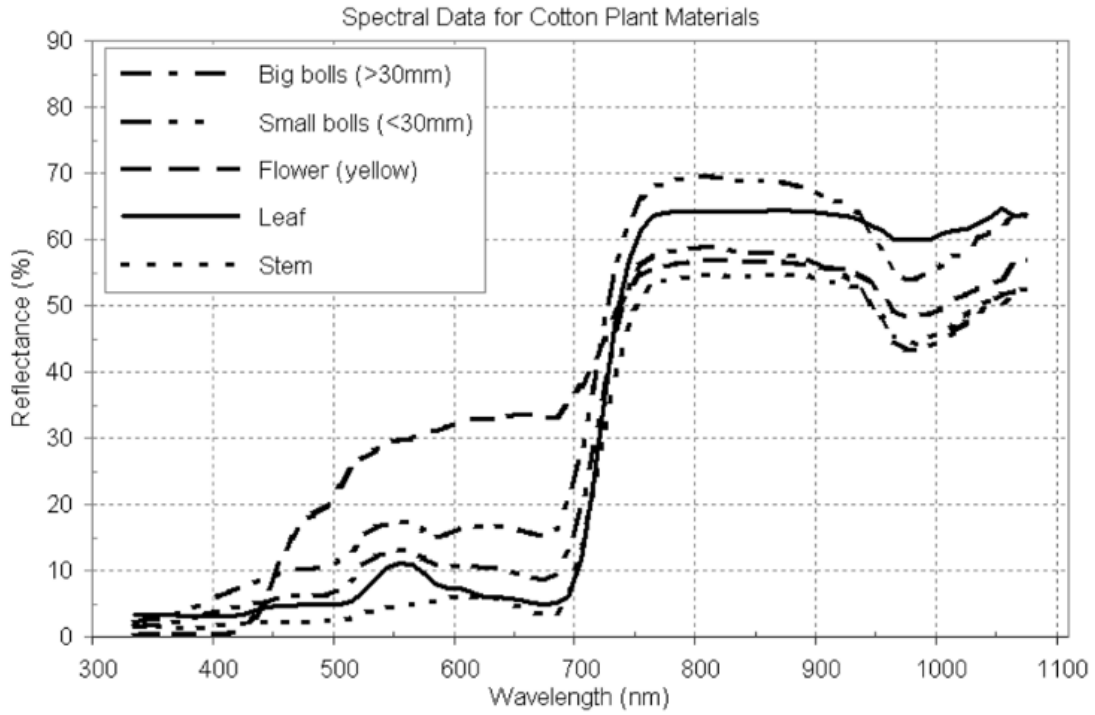
- Light sensors to measure leaf area index

Research tools:

- Distance sensors to measure height and estimate leaf area index
- Image analysis of camera images to determine internode length, nitrogen status and plant size
- Multispectral properties using narrowband imaging

Spectral response of cotton structures

- Flowers could be distinguished from leaf material in red wavelengths 450-700 nm
- At 450-950 nm small bolls have highest reflectance but large bolls not distinguishable

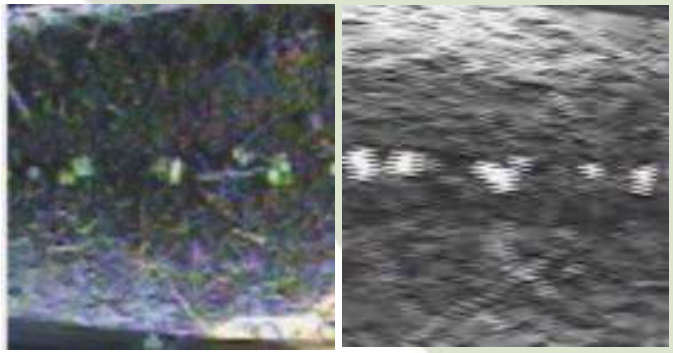


Source: McCarthy, C (2009) *Automatic non-destructive dimensional measurement of cotton plants in real-time by machine vision*. PhD Thesis

Plant density

- Infrared filter increased contrast between leaves, soil, stubble

Visible: Infrared:



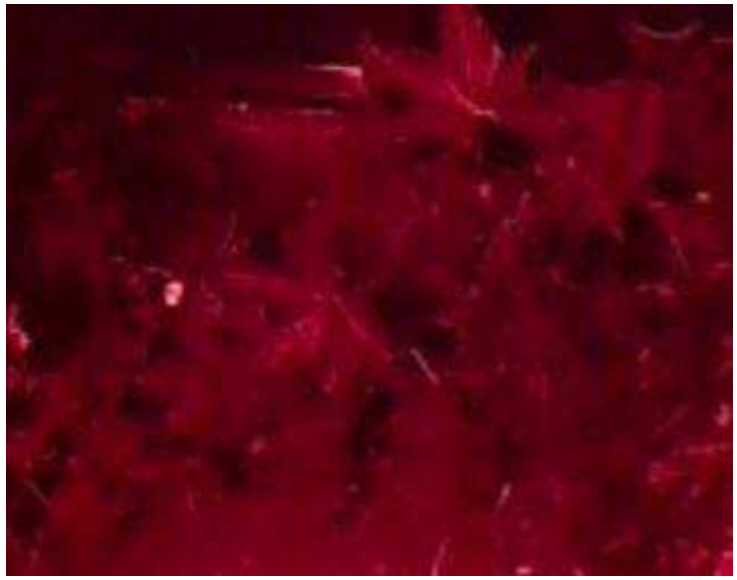
- Image analysis:
  - **Identify potential plants**
  1. Identify leaf (bright) pixels
  2. Assign each leaf pixel to a potential plant number index if connected to another leaf pixel
  - **Size analysis**
  1. Count pixels in each potential plant identified
  2. If count within threshold then a plant is detected and accumulate plant count

Square count

- Square spectral response is similar to leaves
- 21 days from first formation of pinhead square to white bloom, flowers last for 7 days
- Image analysis as for plant density but bright pixels are flowers

Visible:

Red only:



Boll count

- Boll shape can be distinguished from leaves
- Image analysis:
  - **Identify potential bolls from brighter pixels**
  - **Shape analysis**
  1. Count width and height of each potential boll
  2. If dimensions within thresholds then potential boll
  - **Size analysis as for plants and flowers**

Visible:

Infrared:

Platforms for surface irrigation

- Evaluated in the 2010/11, 2011/12 and 2012/13 cotton growing seasons

Ground-based platform for surface irrigation

Vehicle-based platform for surface irrigation

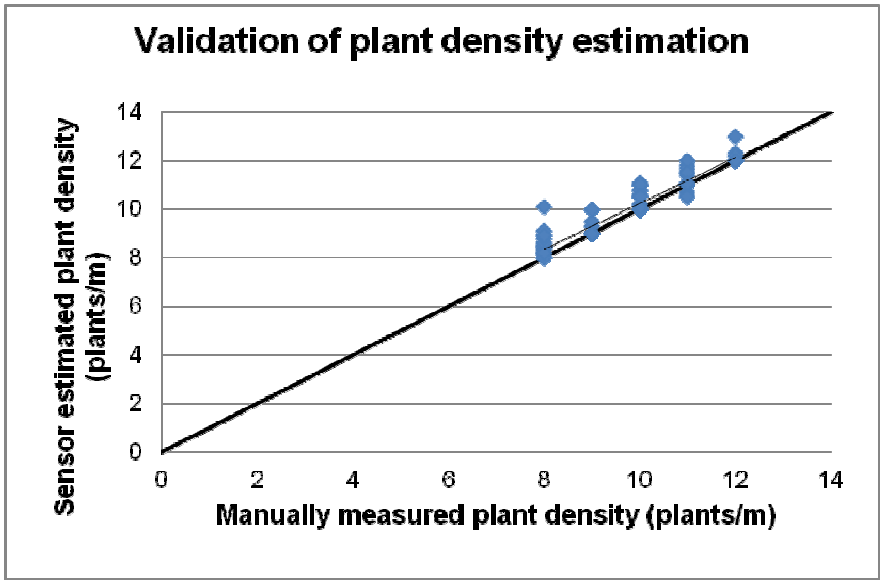
Irrigation machine mounted platform

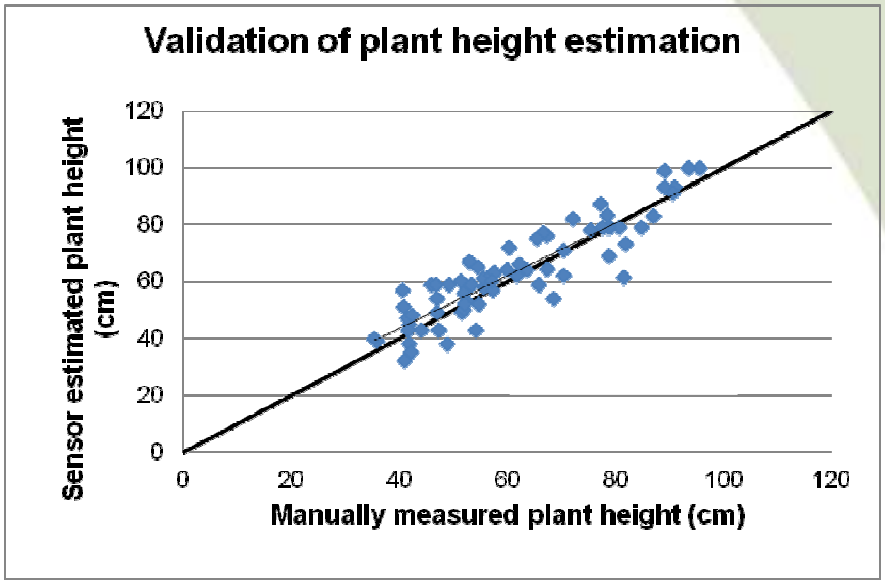
- Evaluated in the 2012/13 cotton growing season

Overhead-mounted platform for centre pivots/lateral moves

Sensor validation – density and height

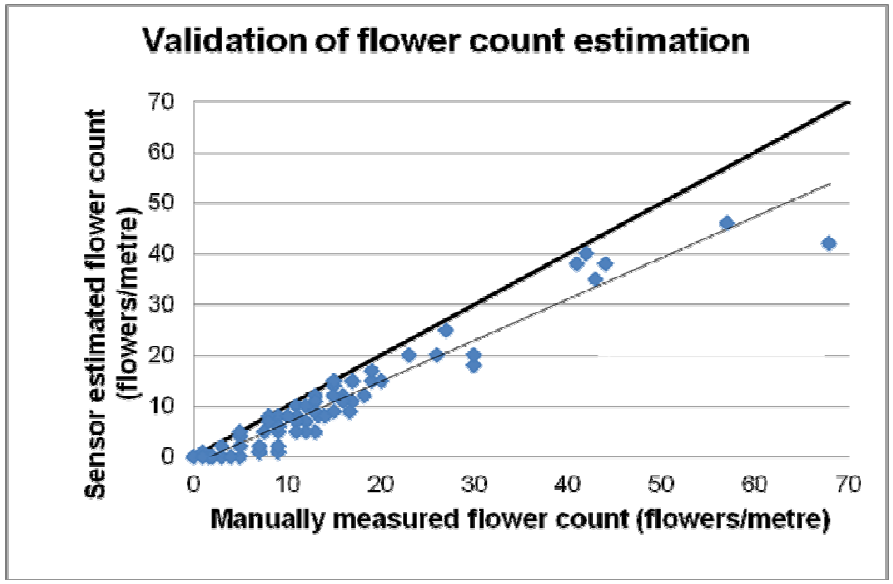
- Plant density generally overestimated from falsely identifying weeds or stubble in the image as small cotton plants
- Accuracy of distance sensor was ±6 cm (±4 cm in specification)

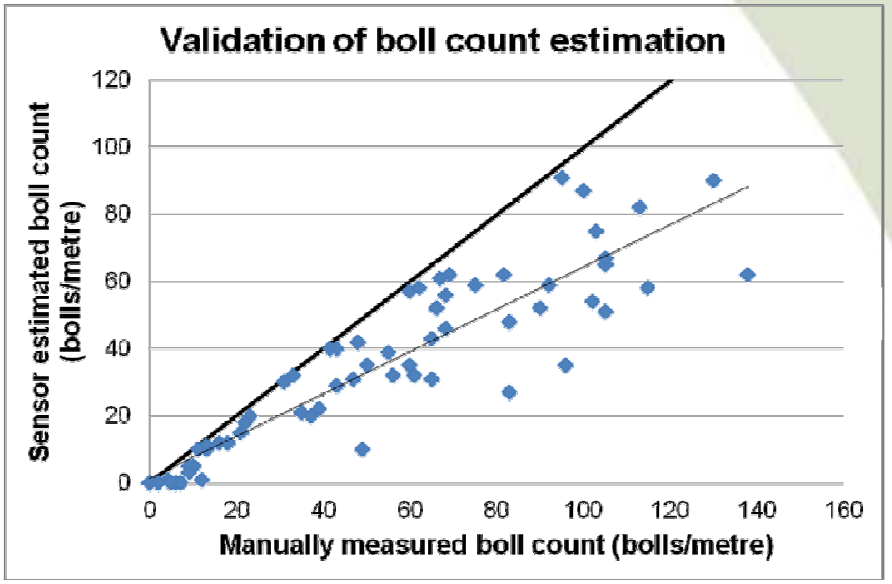




Sensor validation – flowers and bolls

- Underestimated flower count from occlusion by cotton leaves
- Boll count was underestimated because bolls lower on the plant were fully occluded in a top view of the crop





Conclusion

- Plant density and flower and boll count estimation was achieved with simple image analysis in red and infrared wavebands
- Plant height estimation using height sensors
- Sensing platform is suitable for on-the-go sensing of cotton plant parameters at high spatial resolution
- Additional side cameras required for improved boll detection

Potential use for estimating plant parameters in an automated irrigation system

Acknowledgements

- Cotton Research and Development Corporation
- Nigel Hopson and Lindsay Evans for providing field trial sites

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