Automated Canopy Estimator(ACE): Enhancing Crop Modelling and Decision Making in Agriculture

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Outline

- Motivation
- Evaluation
- Results
- Validation
- Conclusion

Motivation

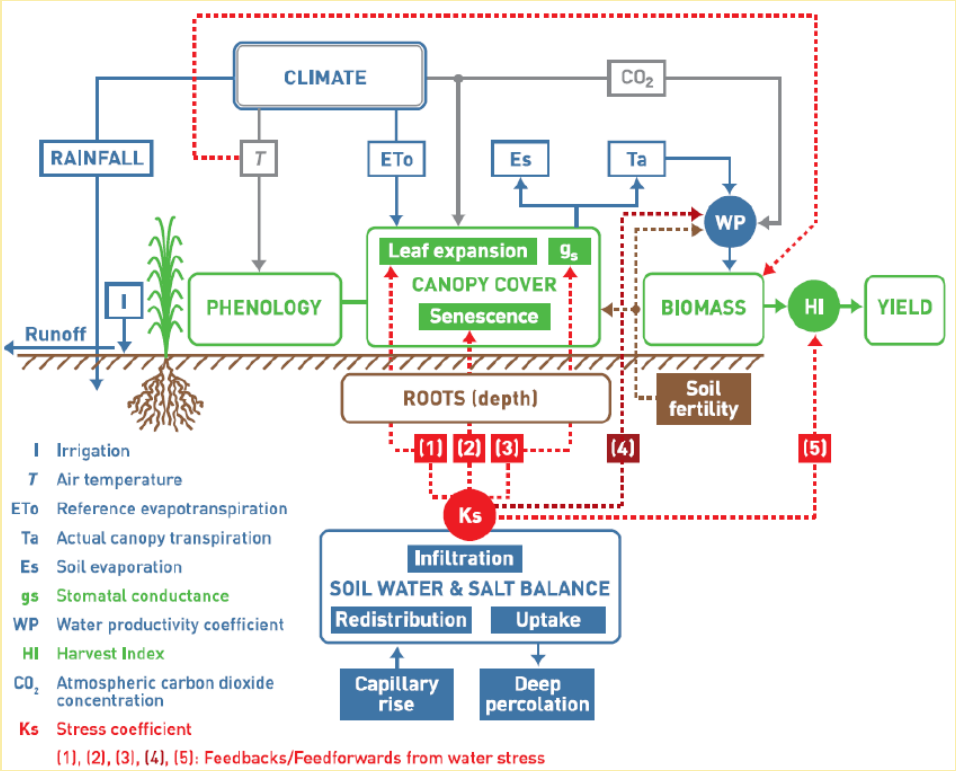
How much of this photograph is covered by corn plants?

Motivation

- Several measures of crop development can be estimated by determining the amount of canopy cover (CC); these are useful for:
  - Determining Nutritional status
  - Identifying Growth characteristics
  - Crop identification
  - Crop Modelling

Motivation

- Canopy cover is a key input to the AquaCrop model



Flowchart of *AquaCrop* indicating the main components of the soil-plant-atmosphere continuum (Steduto, 2008).

Motivation

- Estimating CC from digital photographs is becoming increasingly important
- Using image processing software, such as Photoshop, it is possible to segment the green canopy from the background material
- This is clearly labour intensive.
- The issue of subjectivity also arises

Motivation

- There exist other tools for segmenting images
- Existing approaches are either:
  - Inaccurate
  - Time consuming
  - Subjective, or
  - A combination of all three
- The aim was to develop a simple, low cost, automated, and accurate method for segmenting digital images and estimating canopy cover

Existing Approaches

- Traditional techniques can be separated into two groups: threshold based approaches and machine learning approaches
- Thresholding approaches typically plot a histogram of colour values and attempt to find a value that demarcates green from background
- Machine learning approaches use more sophisticated techniques, such as neural networks and other pattern recognition algorithms

Existing Approaches

- A comparison of CC estimates (derived from the photo above) for different approaches

Approach	Method	Canopy Cover (%)
Photoshop	Threshold (Ground Truth)	58.5
Colour Index of Vegetation Extraction (CIVE)	Threshold	63.8
Extra Green (ExG)	Threshold	33.1
Visual Vegetation Index (VVI)	Threshold	31.0
Green Crop Tracker	Threshold	69.5
Bai et al. (2013)	Machine Learning	53.7

Limitations of Current Approaches

- They do not work well when photos taken with multiple cameras are analysed together
- Most are very sensitive to differences in illumination
- Closed and open canopies are difficult to segment
- Not all are fully automated
- Some need to be retrained for new crops

ACE

- Automated Canopy Estimator (ACE) is a thresholding approach that overcomes many of the limitations listed above

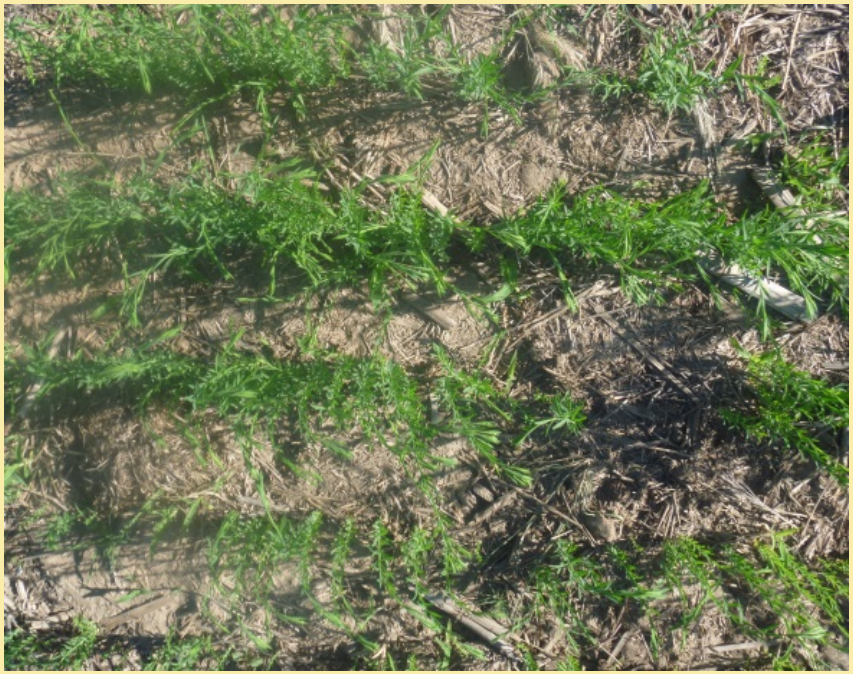
- ACE differs from other thresholding techniques in two aspects:
  - The method of estimating the threshold, and
  - The colour space in which it performs segmentation

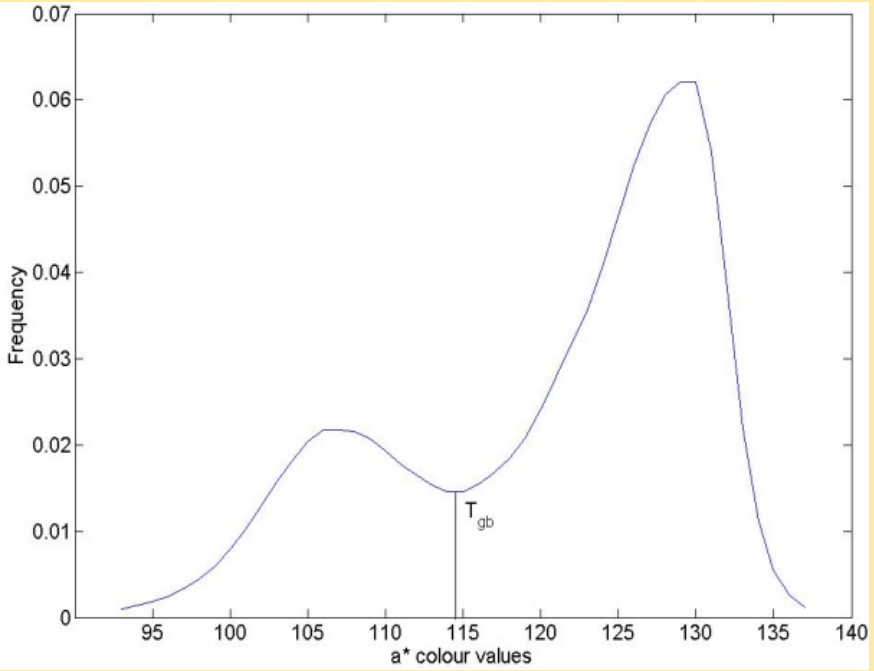
ACE

- ACE works in the CIE L*a*b* colour space
  - Lab space separates illuminance from colour information
- The a* channel is of interest because it represents colours on the spectrum from red to green
- ACE extracts the a* channel and processes it in order to segment green from background

ACE

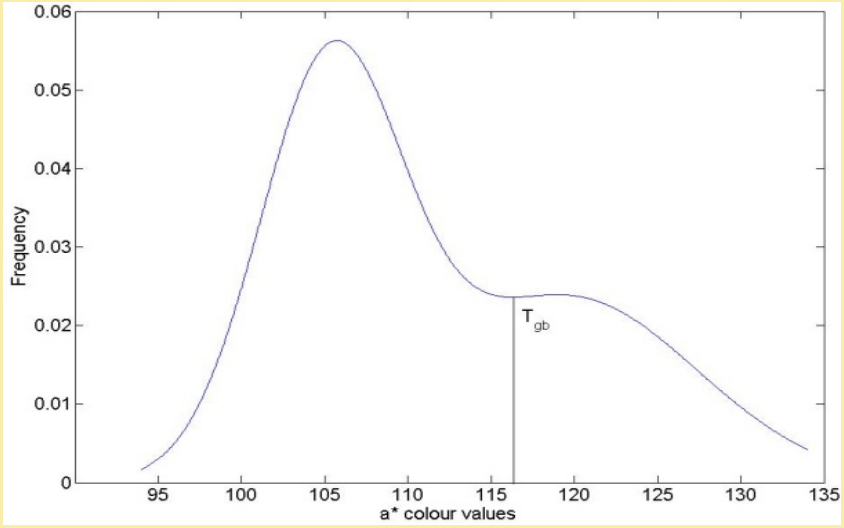
- The probability distribution of a* values is plotted and the threshold is determined to be the point on the x-axis that best delineates green and background





ACE

- The threshold isn't always obvious, so ACE estimates a Gaussian mixture model from the data
- If the distribution is not strongly bi-modal, the inflection point is detected and used as the threshold



Evaluation

- Four separate crops, photographed with two different cameras are chosen for evaluation. The crops are oat, flax, corn and rapeseed.

- The four are chosen because they have different leaf shapes, sizes, orientations, a variety of growth patterns and are photographed under varying lighting conditions

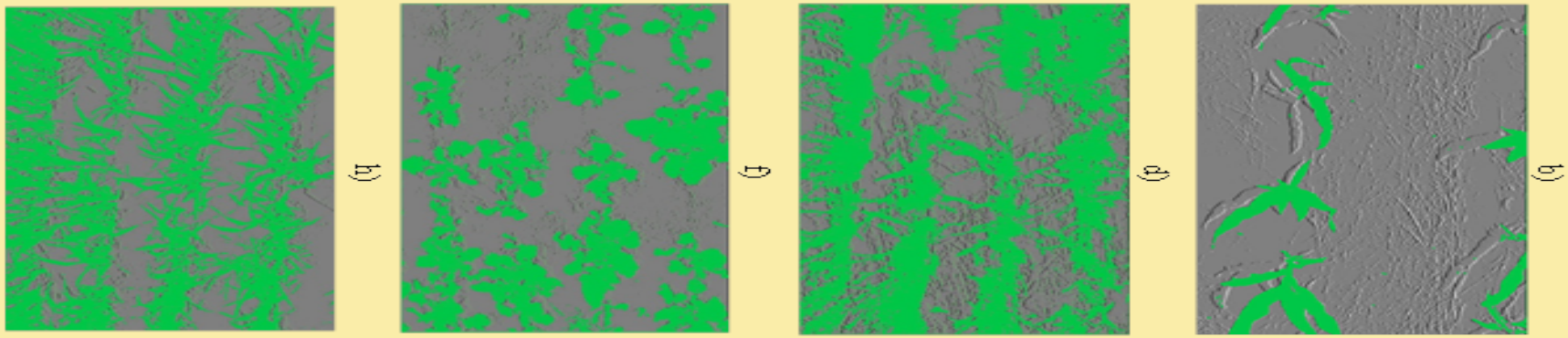
- 80 images are included in the evaluation

Results

- Demonstration of the segmentation output from ACE

Un-segmented

Segmented



Oat | Rapeseed | Flax | Corn

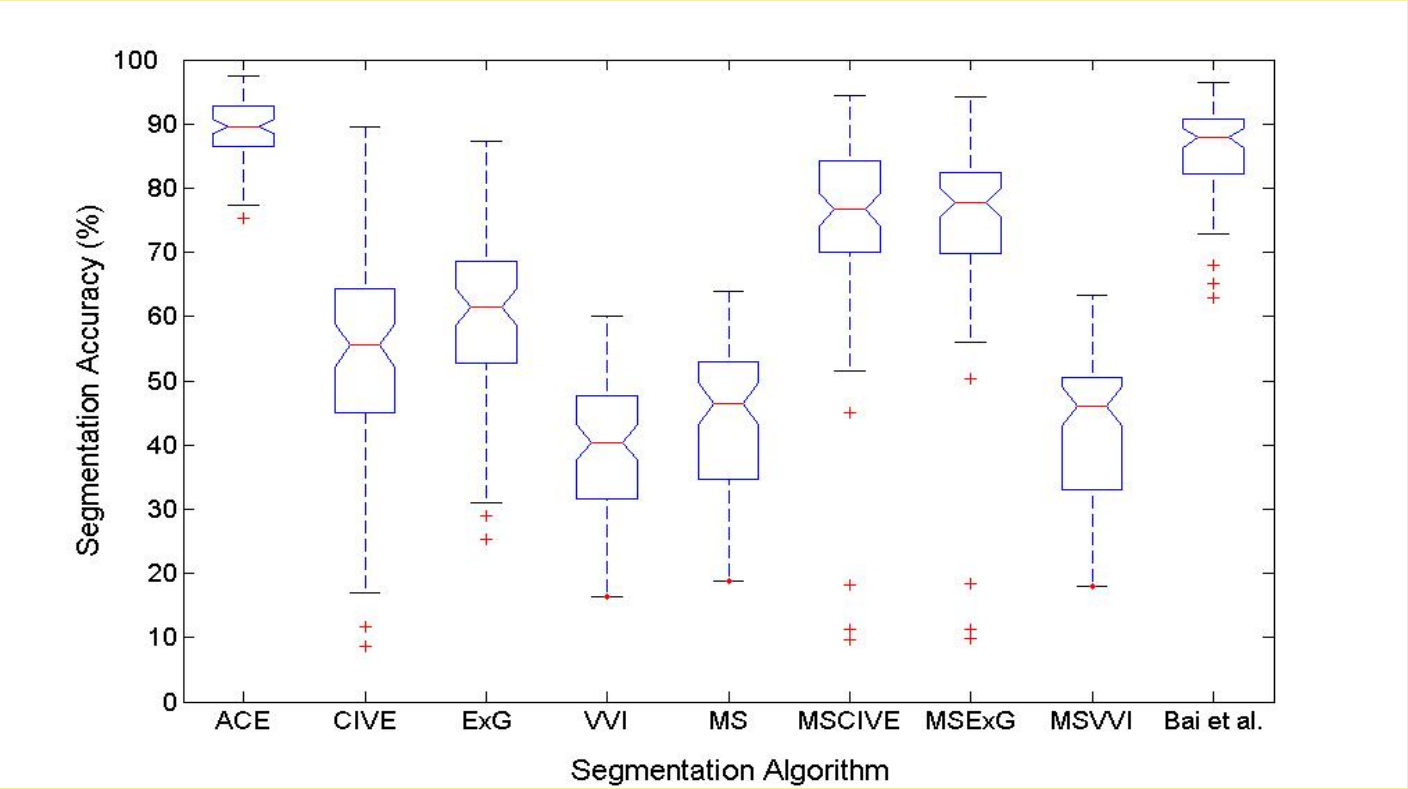
Results - Segmentation

- Comparison of mean segmentation accuracy estimated by ACE and eight other tools

	Corn		Oat		Flax		Rapeseed	
	μ(%)	σ (%)	μ(%)	σ (%)	μ(%)	σ (%)	μ(%)	σ (%)
CIVE	40.0	18.0	63.0	8.0	60.0	18.0	51.0	1.5
ExG	67.0	8.0	58.0	9.0	63.0	16.0	50.0	1.5
VVI	30.0	8.0	45.0	9.0	48.4	10.0	39.4	10.0
MS	35.0	9.0	54.0	7.0	48.0	10.0	43.1	13.0
MSCIVE	85.4	6.0	61.0	25.0	74.0	6.0	75.4	10.0
MSExG	85.0	7.0	62.0	25.0	73.0	6.0	76.0	8.0
MSVVI	32.3	9.0	55.0	7.0	44.0	10.0	42.0	12.0
Bai et al	88.0	5.0	85.0	6.4	84.4	7.7	87.0	8.1
ACE	**89.4**	**3.0**	**90.0**	**5.0**	**88.3**	**5.2**	**89.2**	7.0

Results - Segmentation

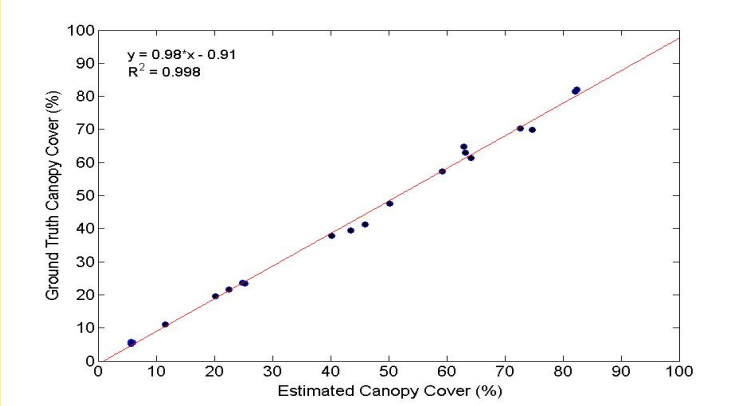
- A graphical representation of the comparison of segmentation accuracy estimated by ACE and eight other tools



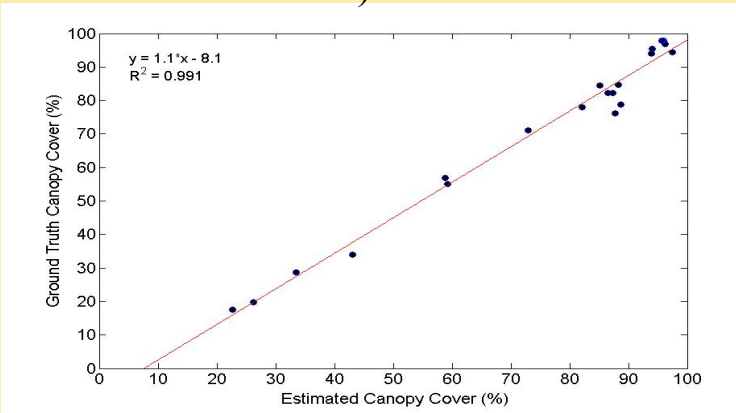
Results – Canopy Cover

- Comparison of ground truth and ACE-estimated canopy cover values for corn (a), rapeseed (b), flax (c) and oat (d)

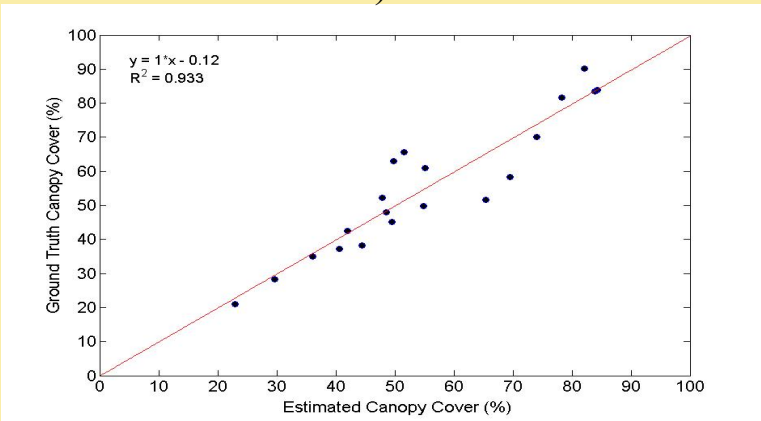
a)



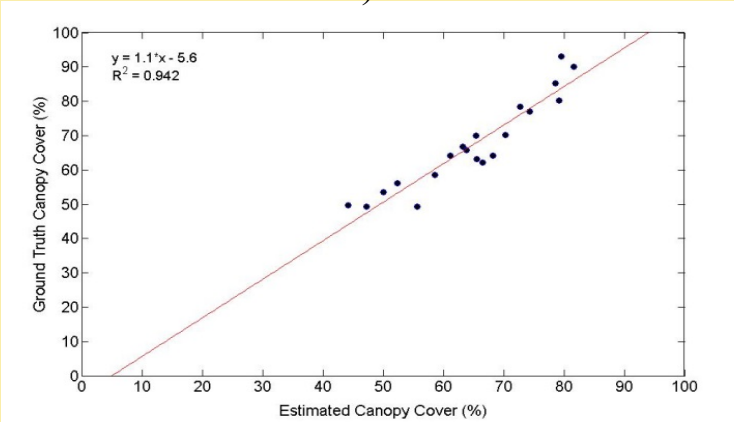
b)



c)

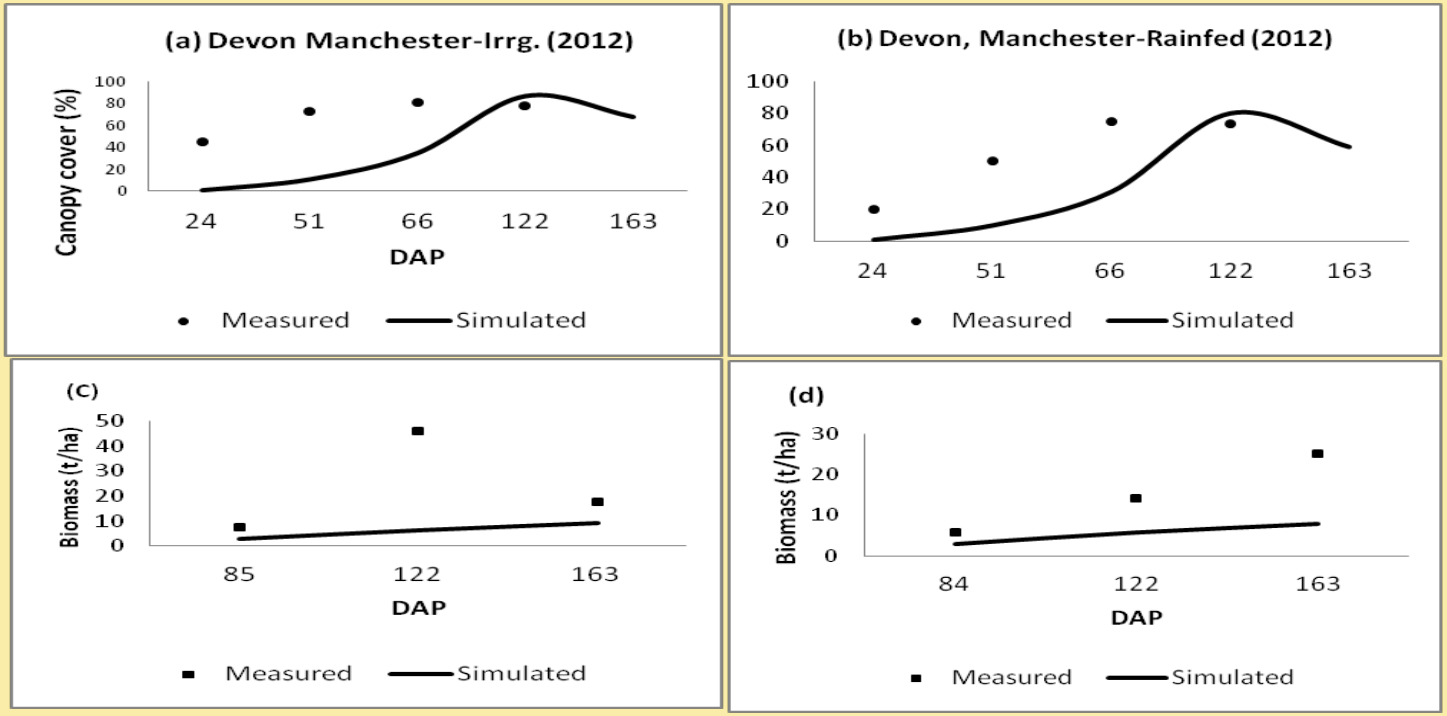


d)



Validation – AquaCrop Simulation

- **TOP -** Simulated (line) versus measured (filled circles) canopy cover **BOTTOM -** Biomass (filled squares) of sweet potato for rainfed and irrigated treatments at Devon, Manchester (2012).
- CC measured using the Green Crop tracker (Liu and Pattey, 2010)



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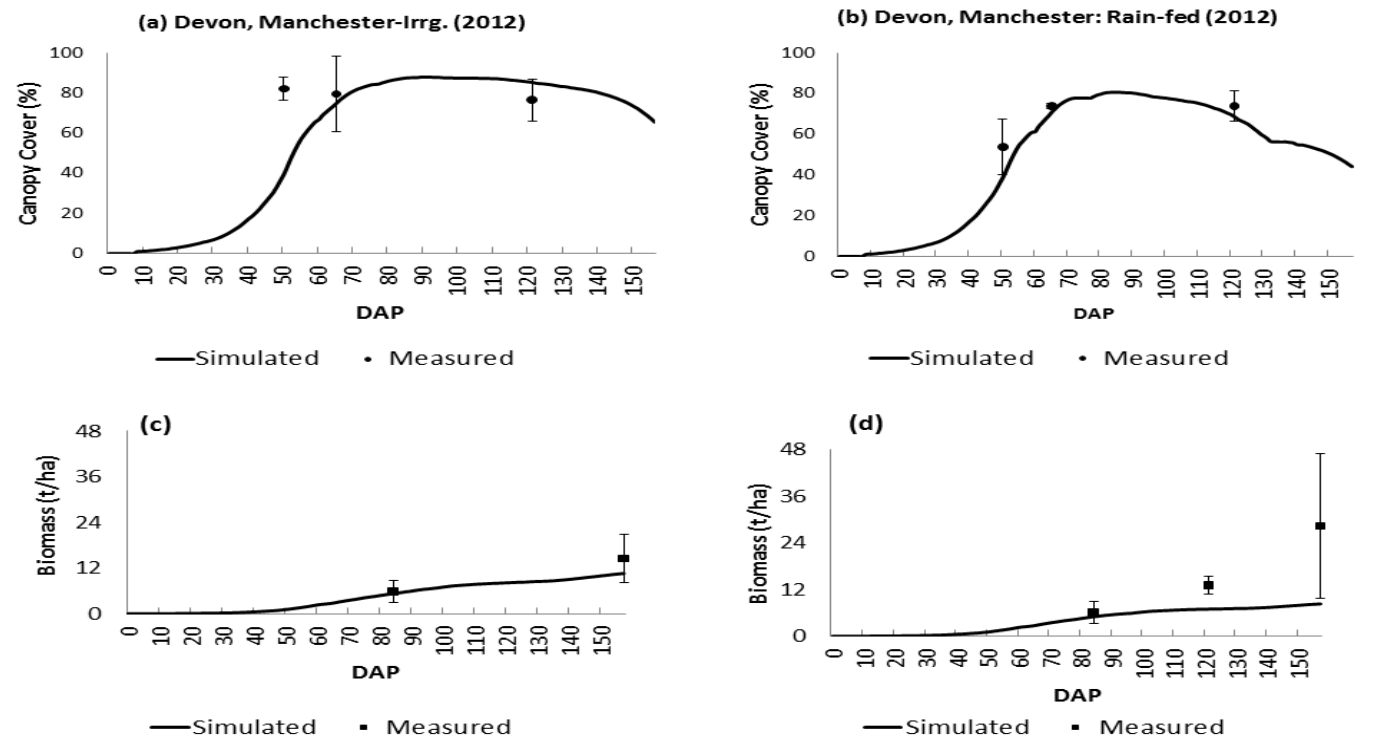

Validation – AquaCrop Simulation

- Canopy cover estimates are used in the parameterization of Sweet potato in AquaCrop (Rankine et al., 2015)
- With CC measured by ACE there is excellent agreement between simulated and measured CC
- AquaCrop creditably simulates the biomass at both locations and for the two treatments using the input of CC estimated by ACE
- When CC is well estimated, Biomass is well simulated

Conclusions

- ACE is an accurate method for segmenting digital photographs and estimating CC
- It overcomes many of the limitations of previous approaches
- It is an automated method for estimating CC from digital photographs and is potentially beneficial for many applications, including crop modelling.

In case you were wondering …

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ACE	Threshold	58.6

Availability of ACE

- ACE is online: http://173.230.158.211