Cotton growth and productivity using sensing technologies and biophysical models

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Introduction

WHY?

Cotton is a crucial cash crop with a total value of around $50 billion and an international trade of $20 billion, mainly for lint (fibre) and seeds [1], supporting livelihoods for approximately 100 million farmers across 80 countries. Australia is known for producing high quality and contaminant free cotton.

AUSTRALIAN COTTON PRODUCTION:
The figure 1 outlines the yield (t/ha) trend across 32 seasons of the top five cotton producers. Despite the fluctuations, the Australian cotton yield is higher than other countries and world average. This is given by three main reasons:
1) The use of advanced farming practices
2) The cultivation of high-yield varieties
3) The world's most water-efficient cotton producer

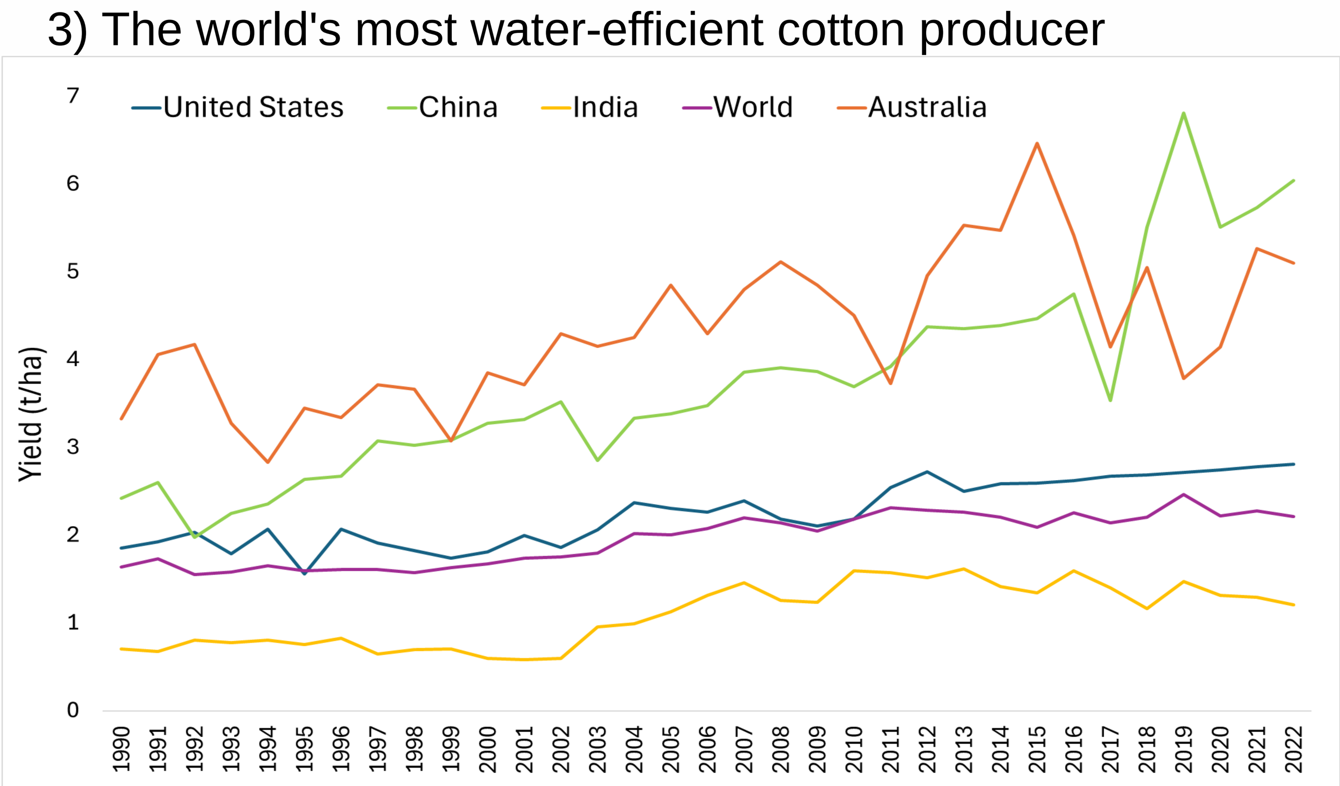

Figure 1: World & Australian cotton yield [2]

VARIABILITY IN GROWTH AND PRODUCTION:

The drivers of cotton growth and production result variability in the final yield (Figure 2).

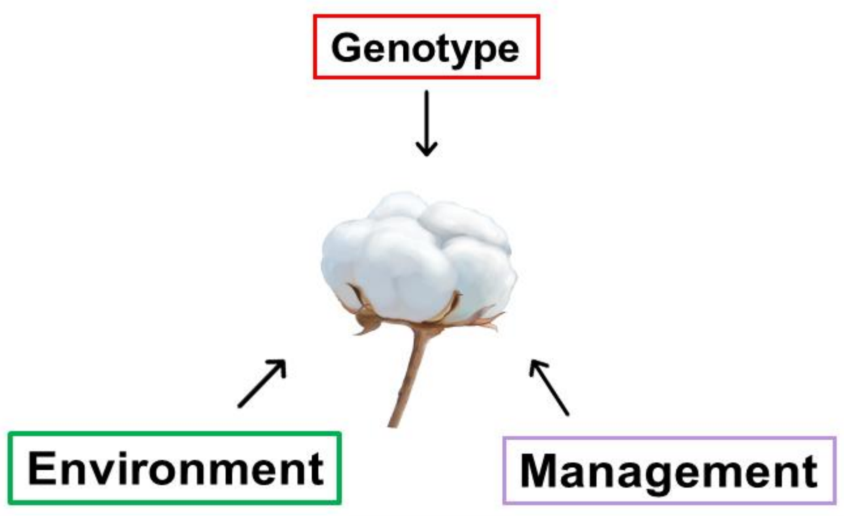

Figure 2: Main drivers of cotton growth and production

CHALLENGES:

- Rapidly and cost effectively measuring spatial variability
- Objectively informing management of cotton production at field and farm scales
- Understanding the drivers of cotton production during extreme events across regions and seasons

Traditional methods for assessing cotton growth are labor-intensive and expensive.

PROPOSED SOLUTIONS:

The advent of high-resolution Earth Observation (EO) technologies from satellites and Unmanned Aerial Vehicles (UAVs) integrated with machine learning and Radiative Transfer Models (RTMs) offer the opportunity to address these challenges. Specifically, they are non-invasive and efficient in measuring the crop morphological, biochemical, and physiological traits at plant, canopy and field scales [3].

Aims

1) To evaluate the variability in cotton growth and yield, using multispectral and thermal bands from above on multiple dates at canopy level.
2) To derive functional plant properties, employing RTMs driven by multispectral and hyperspectral data.
3) To estimate the effects of stress using thermal sensors at the field scale.

Methods & Approaches

1) Validating multispectral and thermal data with direct observations (physiological, biochemical, and morphological traits)
2) Simulations and inversions with RTMs to get plant properties, using the crop spectral signature and the ground dataset.
3) Scaling out the calibrated metrics and applying thermal data and stomatal conductance at the field level.

Outcomes

1) Metrics to determine the effects of management practices on cotton phenotype and yield.
2) Calibrated integrated model from scaling out of metrics across fields, to estimate variability in different phenological stages
3) Real time info on crop health to facilitate the decision-making framework and address sustainability

Preliminary Results

Investigating the potential of proximal sensing metrics derived from multispectral and thermal bands onboard UAVs to estimate variability in cotton production across plots ahead of harvest [4].

The Figure 3 shows the relationships between the nitrogen concentration and the Canopy Chlorophyll Content Index ($CCCI_{NDVI}$) [5] and the same index by canopy temperature (CT). The scatterplots elucidate that these metrics can be used as proxies of plant health according to the trends: a positive one between the observed data and the VI (left side) and a trapezoid space with a negative relationship (right side).

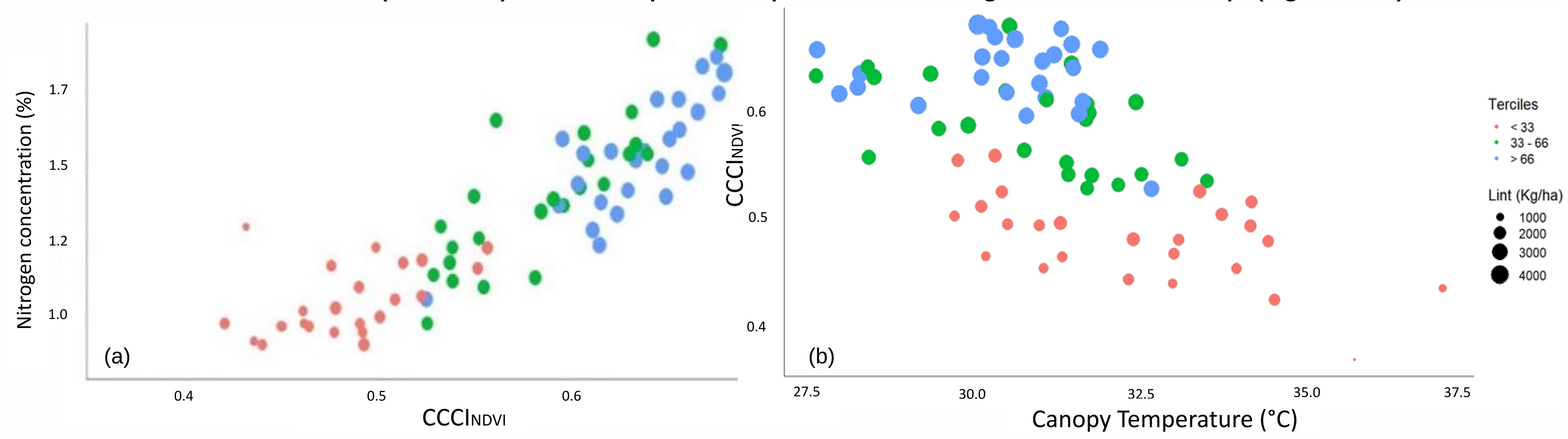

Figure 3: The nitrogen concentration (in % on the dry matter) plotted by the $CCCI_{NDVI}$ (a); $CCCI_{NDVI}$ by the CT (b) values. The size of the dots is proportional to the harvested lint (kg/ha), while the colour relates to their tercile class

Value to Industry

- Offering enhanced insights into traits associated with tolerance to abiotic and biotic stress

- Expediting field data collection

- Supporting decision-making regarding optimal crop management practices to minimize expenses and maximize yields.

References

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[2] Food and Agriculture Organization of the United Nations (2023)

[3] IPCC, "Technical Summary. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change," M.-D. V. et al. Eds. Cambridge University Press, Cambridge, UK and New York, NY, USA., 2021, pp. 33 - 144.

[4] Devoto et al (aim publication 2024)

[5] D. E. Elshikha et al., "Remote Sensing of Cotton Nitrogen Status Using the Canopy Chlorophyll Content Index (CCCI)," Transactions of the ASABE, vol. 51, 01/01 2008, doi: 10.13031/2013.24228.

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