

Assessing crop water use in wheat and sorghum National Variety Trials in Australia

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INVITA: INnovations in **Var**lety **T**esting in **A**ustralia



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Grains Research and Development Corporation

INVITA

The INVITA project proposes to use High-Throughput Phenotyping (HTP) and Env. Characterisation (EC) technologies for:

<https://nvt.grdc.com.au/>

Each year:

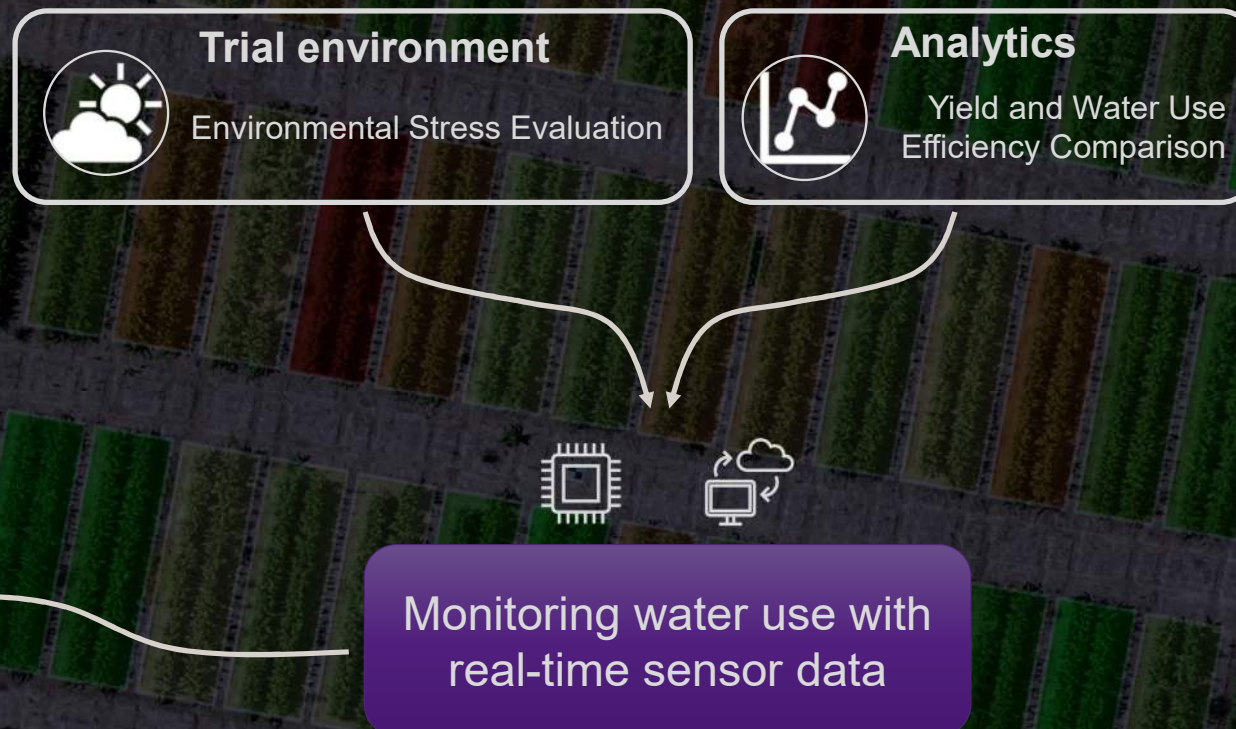
- 650 trials,
- 300 locations,
- 10 species each year

Compare variety performance:

- Grain yield
- Other characters

Compare environmental adaptability:

- Evapotranspiration (ET)
- Water Use Efficiency (WUE)





Energy and evaporation in crops

Conservation of energy

$$R_n - H - G - LE - P - R = 0$$

Involves sensible heat fluxes of air (**H**) the ground (**G**), latent heat flux (**LE**); and chemical bond energy in photosynthesis (**P**) and respiration (**R**)

P and R are generally small (1 to 5% of R_n),

$$R_n - H - G - LE = 0$$

Heat loss through evapotranspiration

(L) latent heat of the vaporization of water (2450 J g⁻¹ at 20 C)



(E) rate of evapotranspiration

H: from the difference between the ambient and canopy temperatures



G: from the penetration of solar radiation in the canopy using green area index (GAI)

Part I

Development of sensor-based ET estimation method for NVT

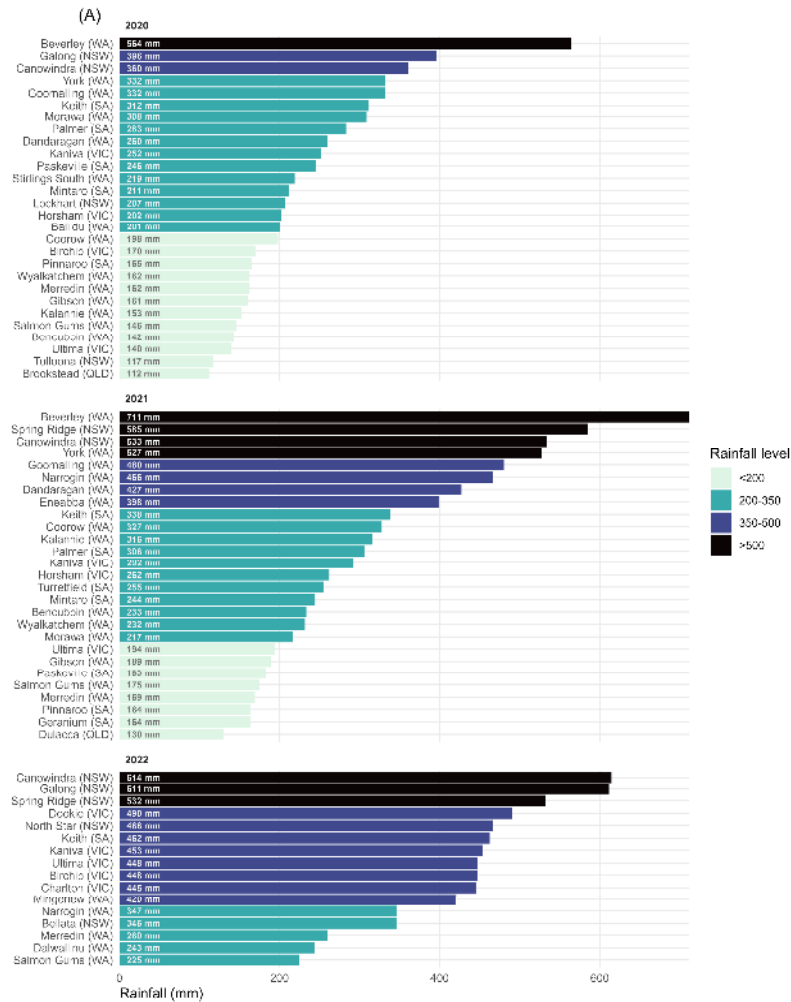
Objective

Evaluate the potential of using thermal infrared sensors and RGB cameras to estimate crop ET in wheat NVT trials





Establishing trials



- Reference locations were selected for monitoring a broad range of evapotranspiration values during the season.
- Historical data on yield performance and rainfall distribution during the season was used.

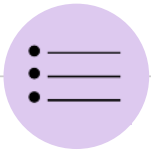
Wheat - Main Season



Sorghum - Main Season



120 wheat and 22 sorghum variety trials monitored



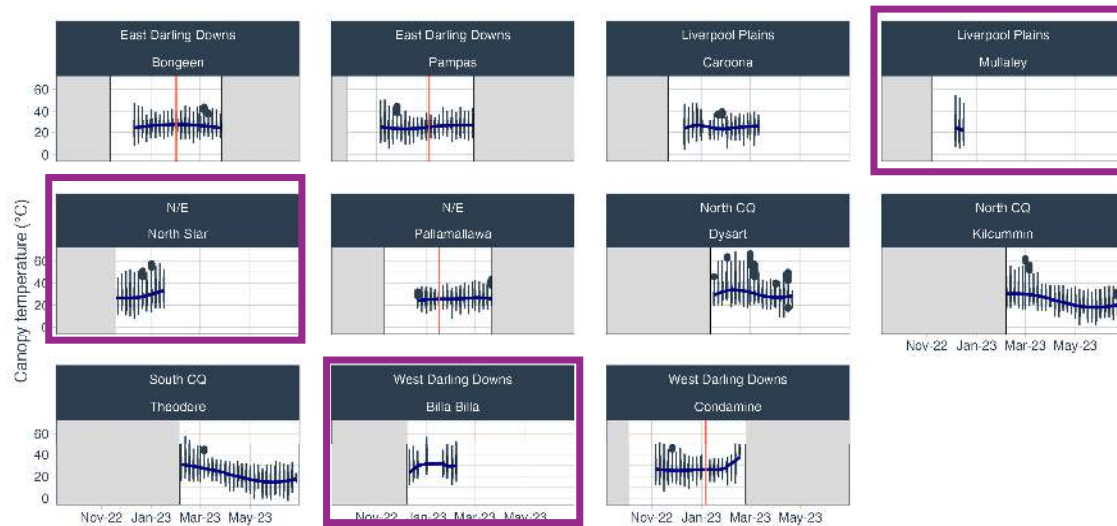
Variables measured

- **Ambient and canopy temperature:**
 - Point-based thermal infrared sensors (Goanna Ag, Australia) were installed at a 45° angle to the canopy.
- **Radiation and humidity:**
 - Weather stations when available in reference trials.
 - SILO spatially interpolated gridded data from BOM (Bureau of Meteorology) stations.
- **Gap fraction and green area index (GAI):**
 - RGB cameras (Swift Enduro 4g model) installed at a 57.5° zenith angle following Baret et al. (2010).

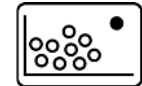




Thermal sensors and RGB cameras



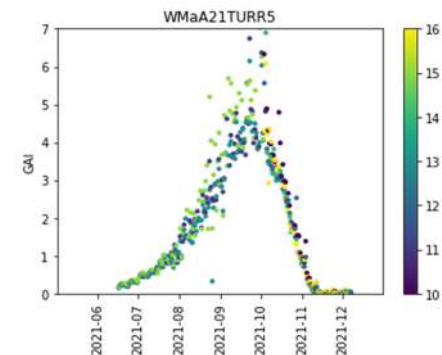
Missing data and anomalies:



- Sensor or battery faults
- Inclement weather
- Network failures,
- Operational issues

Processing RGB images:

- Pixel-based segmentation applied to RGB photos to compute the Green Area Index (GAI) (Baret et al., 2010; Liu et al., 2019).

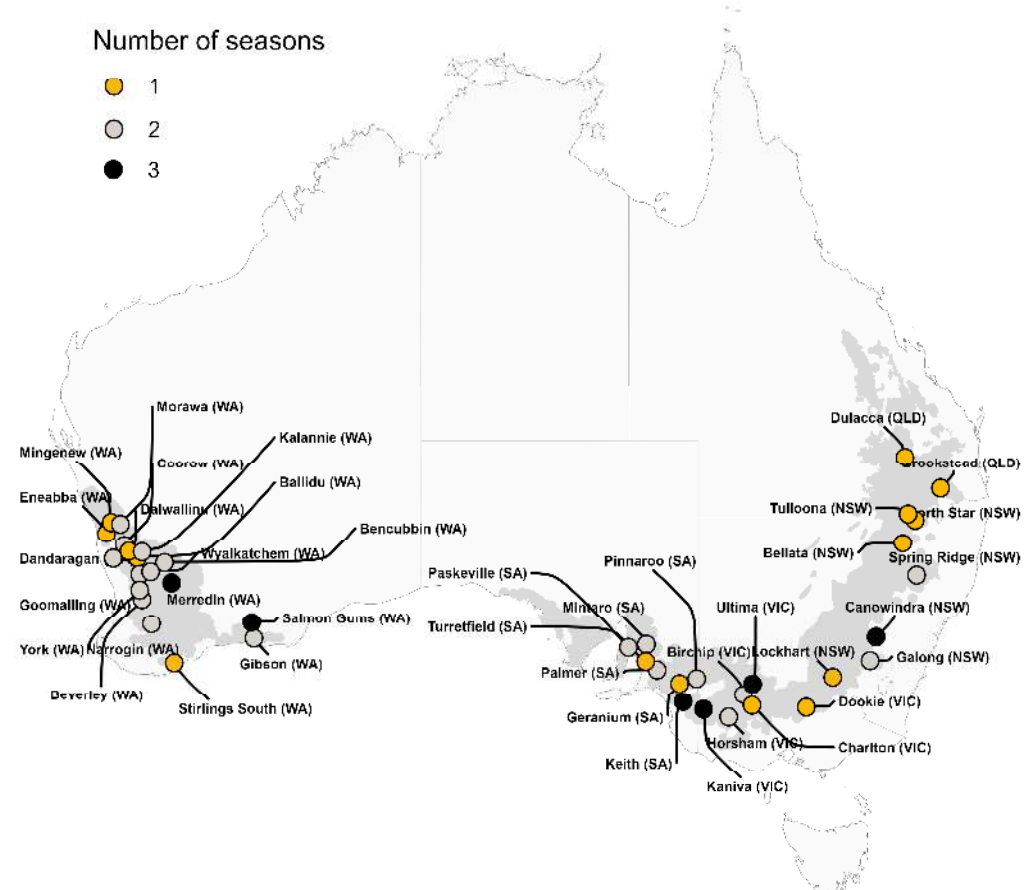




A cost-effective solution?

From the total of 142 trials:

- 48 recorded reliable ambient/canopy temperature **AND** GAI data in more than half of the growing season duration:
 - 45 wheat NVT: *across QLD, NSW, VIC, SA, and WA during 2020 to 2022.*
 - 3 sorghum NVT: *across QLD and NSW during 2022.*
- 26 recorded ambient/canopy temperature **AND** GAI data during critical period
- 68 recorded either ambient/canopy temperature **OR** GAI data

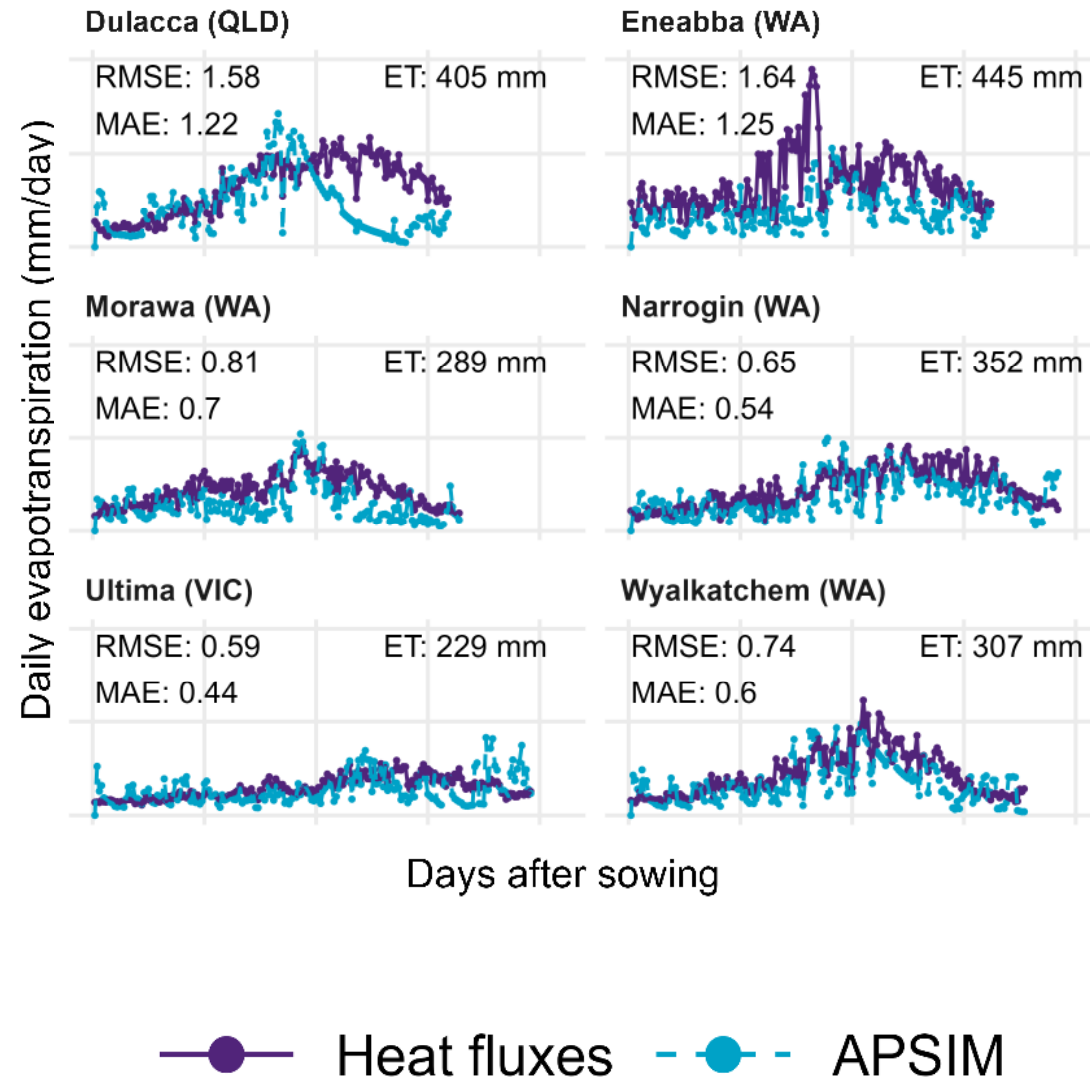


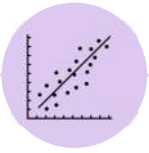
Part II

Crop modelling vs. sensor-based measurements

Objective

Assess the accuracy of crop modelling estimates of ET against sensor-based measurements



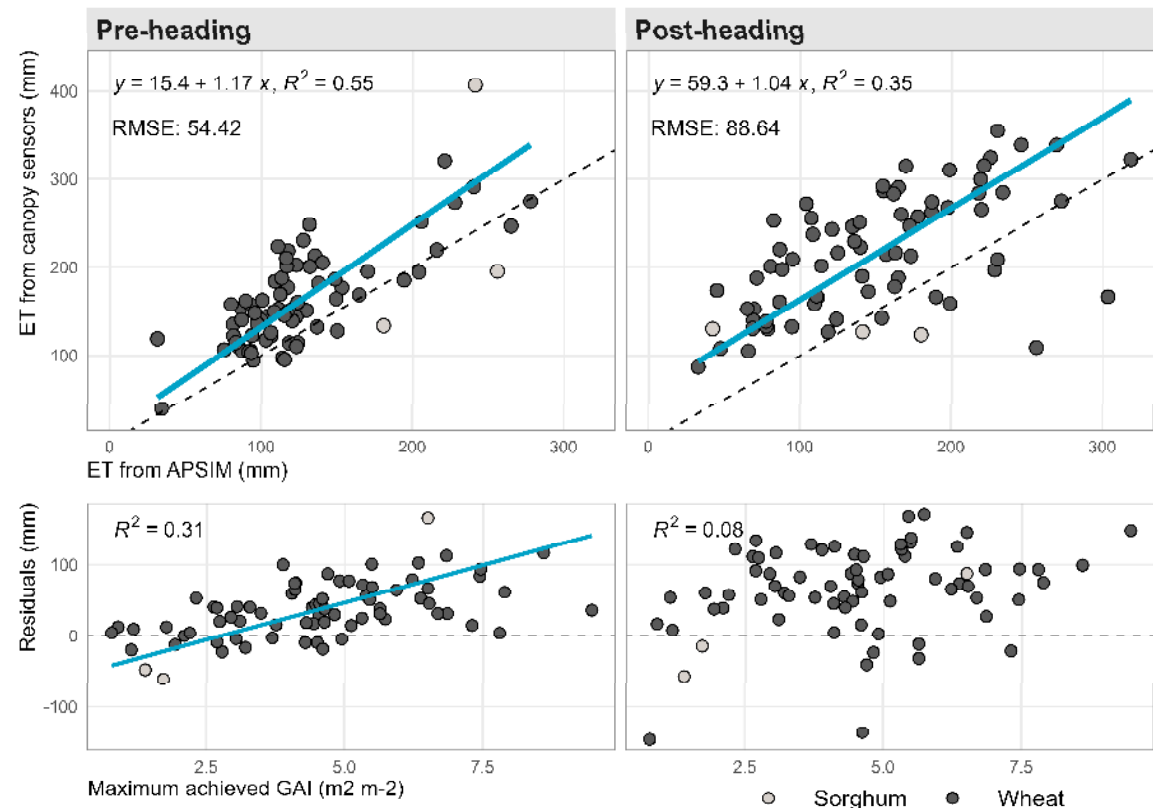


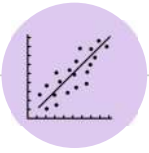
Comparison: seasonal ET

... with APSIM calibration performed based on phenology, growth, and remote sensing satellite data (Hu et al., 2024).

For seasonal ET estimation:

- A moderate agreement between the two methods was obtained but with better performance for the pre-heading period ($R^2 = 0.55$; RMSE = 54.4 mm)
- An overestimation seems to be caused by higher GAI values.

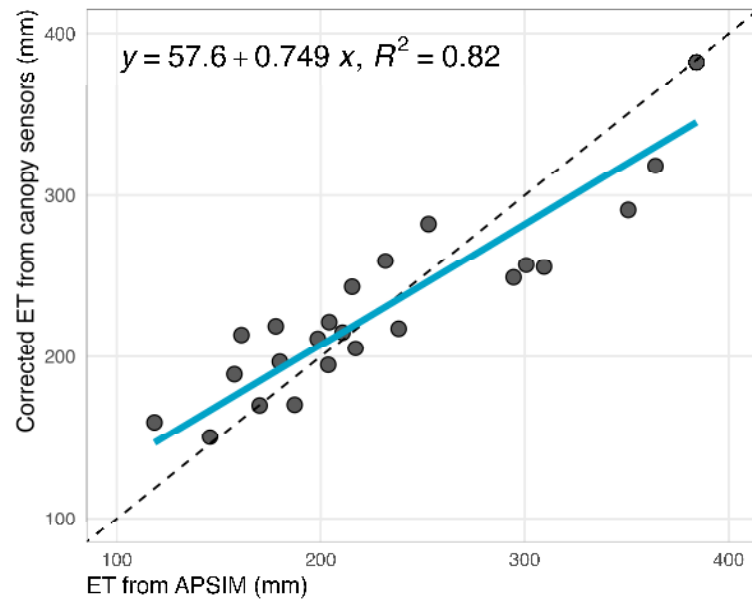




Satellite-based correction

Bias correction adjustment:

- Satellite-based ET estimates from CMRSET algorithm was obtained for each NVT: *Monthly at 30 m resolution*
- Monthly sensor-based ET calculated to be compared against



Data Discovery

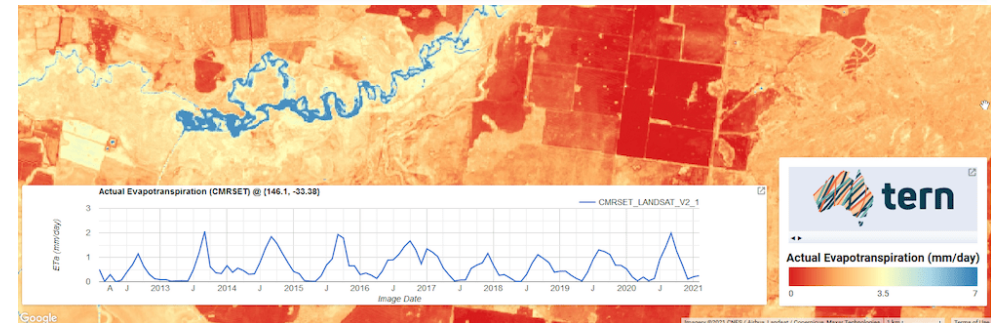
METADATA

Actual Evapotranspiration for Australia using CMRSET algorithm

Ver: 1.0
Status of Data: on going
Update Frequency: monthly
Security Classification: unclassified



Viewed: 228298
Accessed: 3122
Add to Favourites
Export to EndNote



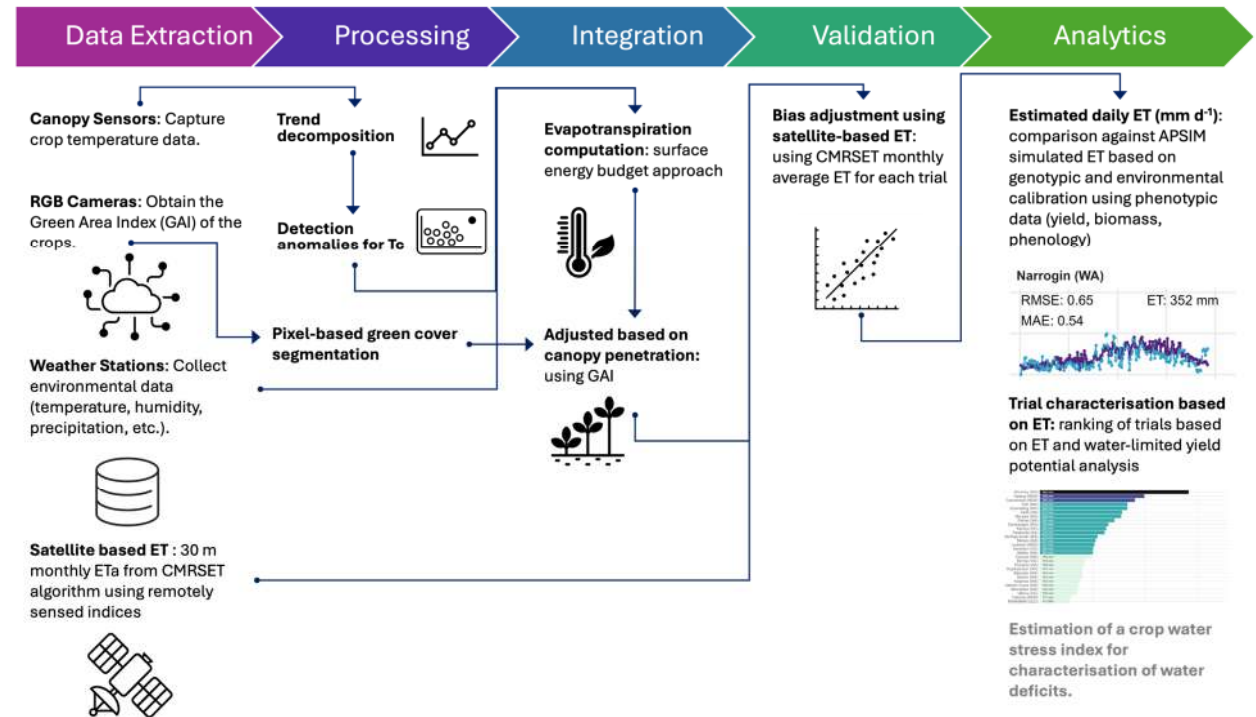
McVicar et al. (2022) <https://doi.org/10.25901/gq27-ck96>



Conclusions

Objective I: *Evaluate the potential of using thermal infrared sensors and RGB cameras to estimate crop ET in wheat NVT trials*

- A data extraction-processing pipeline was developed to estimate in-season evapotranspiration in the field.
- Challenges in maintaining a correct functioning of the sensor readings; however, can still be useful to monitor specific crop stages (e.g. around critical periods).



Objective II: *Assess the accuracy of crop modelling estimates of ET against sensor-based measurements*

- A moderate agreement ($R^2=0.55$) between the two methods, biased under greater GAI.
- Satellite-based ET (at monthly resolution) corrected biases and increased agreement to a $R^2=0.82$.

Thank you

Acknowledgments

Many people involved:

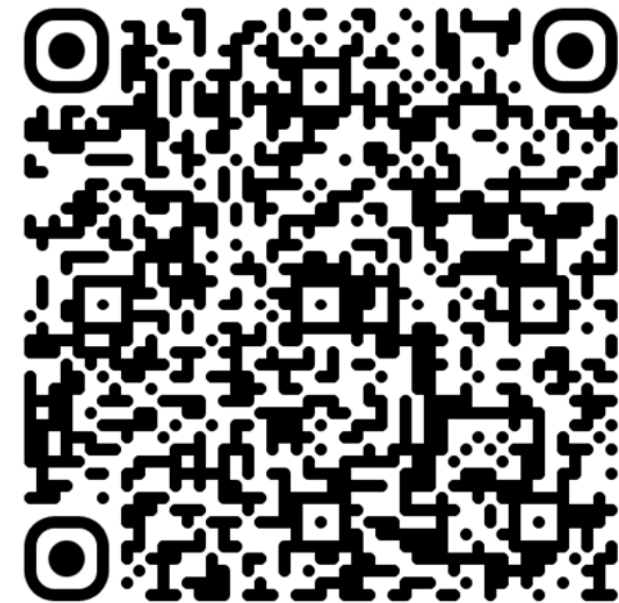
- Prof Scott Chapman
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- Dr. Qiaomin Chen,
- Dr. Daniel Smith
- MSc. Chris James
- MSc. Xiaolong Chen
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