

International Macadamia Symposium 2023



MOVING FORWARD TOGETHER

Macadamias South Africa (NPC)  
(SAMAC)



Mapping, tree age  
modelling and yield  
predictions: Where is  
this going to take us?

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Dr Andrew Clark                                Sharon McGavin  
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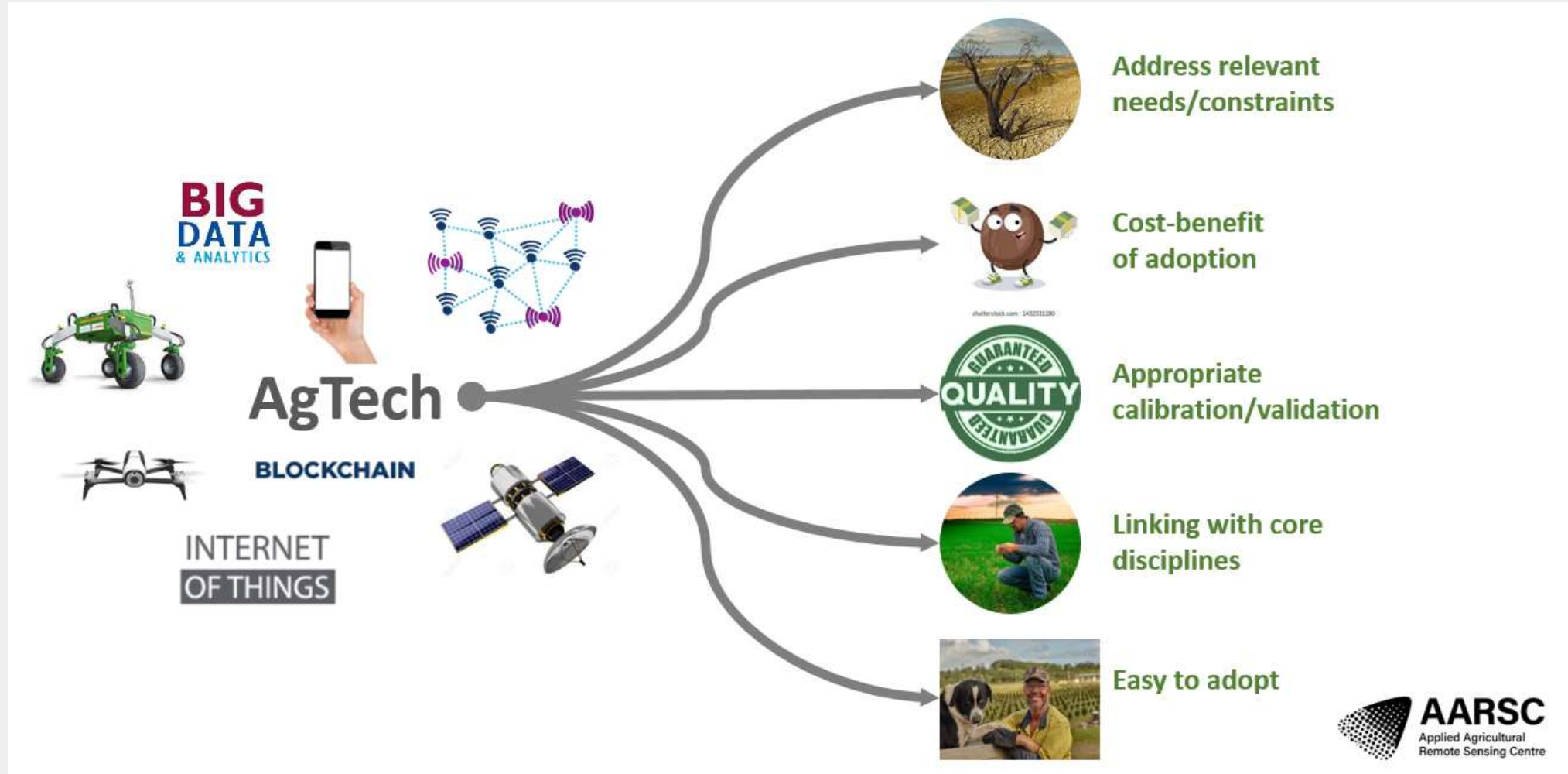
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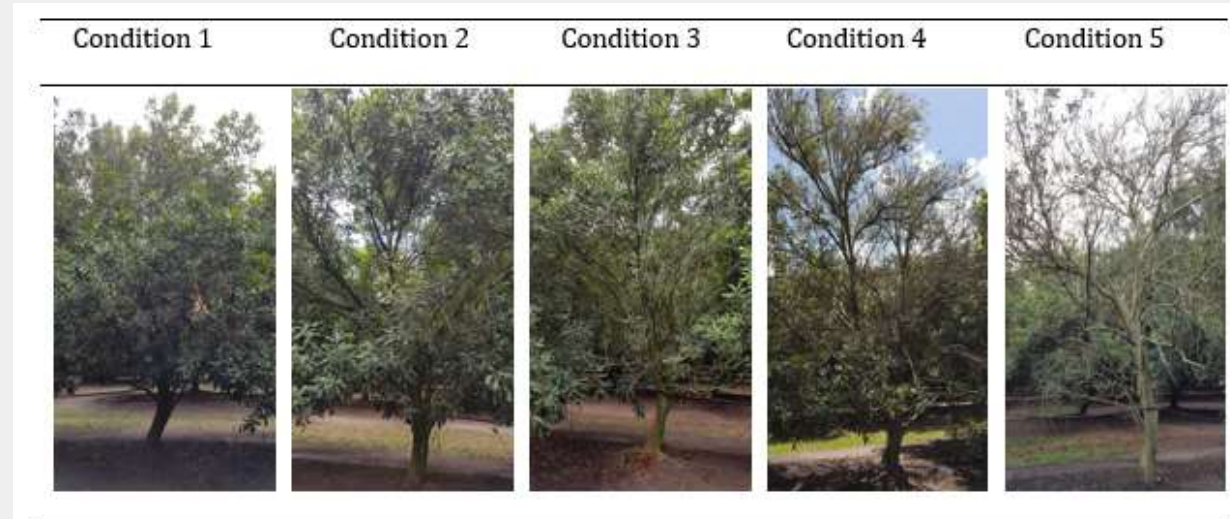
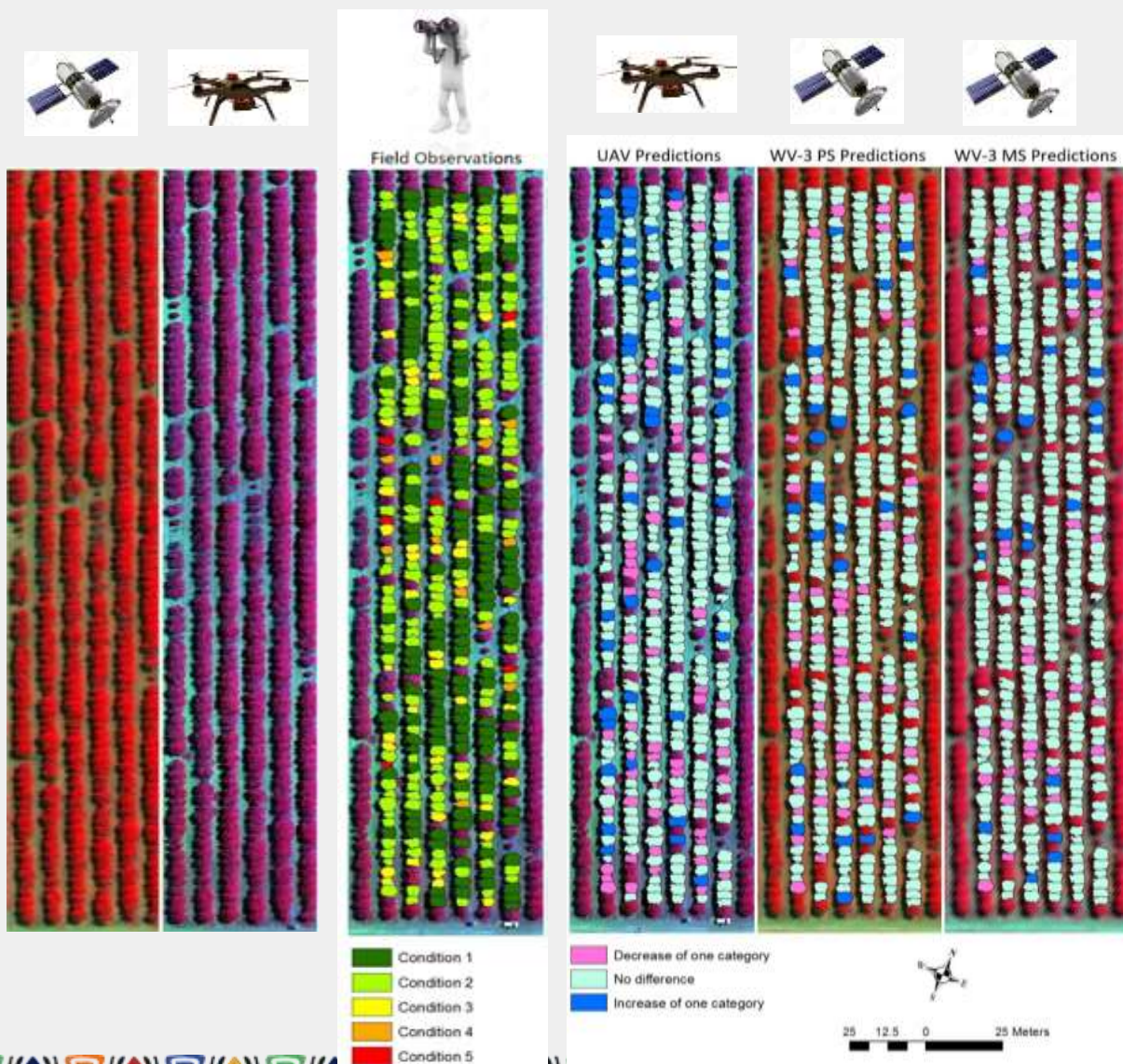
# There are a lot of AgTech:



# Application is the key, not the tech:



# Mapping macadamia tree condition:

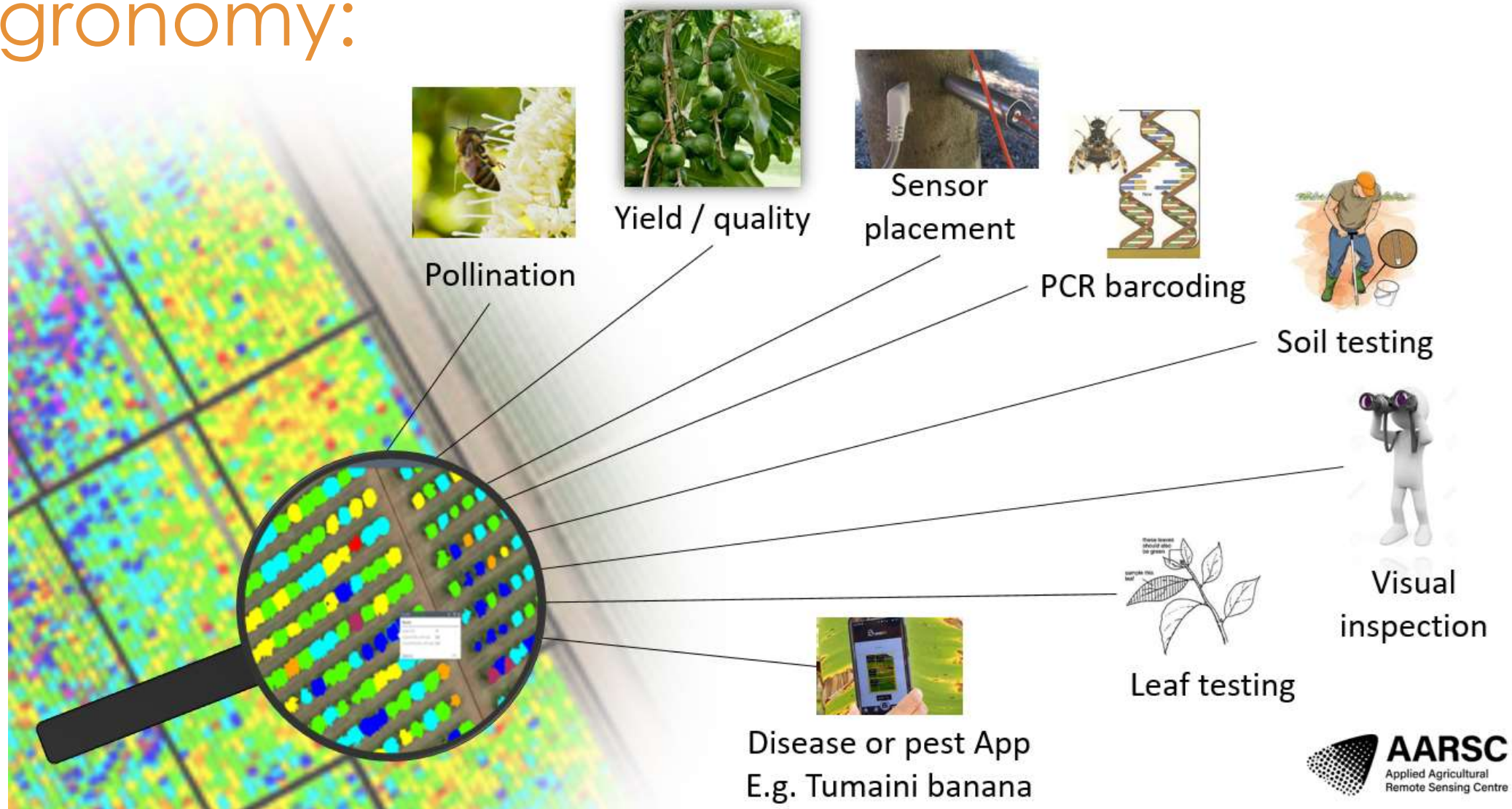


Mapping the condition of macadamia tree crops using multi-spectral UAV and WorldView-3 imagery

Johansen, Kasper, Duan, Qibin, Tu, Yu-Hsuan, Searle, Chris, Wu, Dan, Phinn, Stuart, Robson, Andrew, and McCabe, Matthew F. (2020). *Mapping the condition of macadamia tree crops using multi-spectral UAV and WorldView-3 imagery*. *ISPRS Journal of Photogrammetry and Remote Sensing* 16528-40. <https://doi.org/10.1016/j.isprsjprs.2020.04.017>



# Mapping variability supports targeted agronomy:

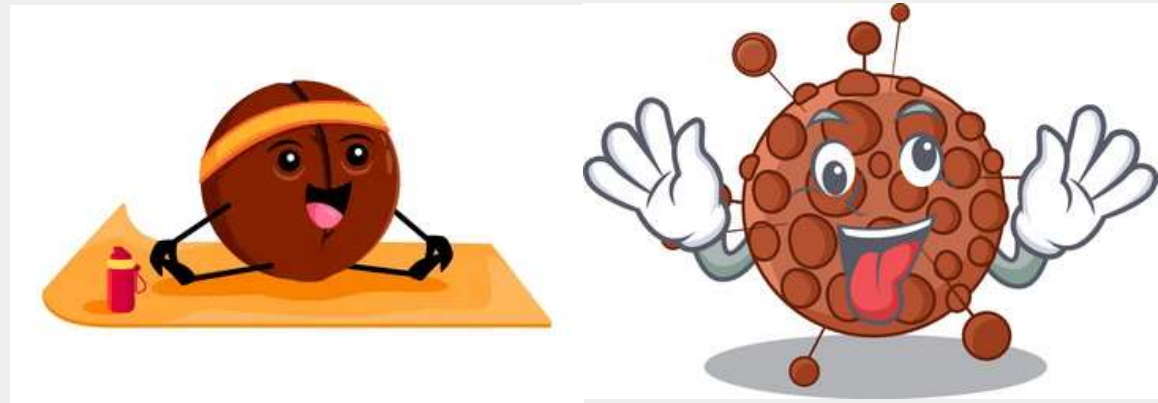


# Nut Applications:

- Yield



- Quality and Disease



# Yield forecasting and mapping:

Biggest problem is you can't see the Nuts for the trees





# Yield monitoring:

The hard way



The mechanised way

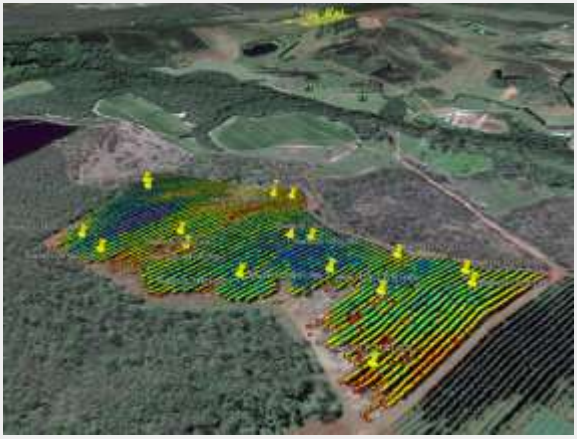


Downside is yield variability is only measured at commercial harvest, therefore that data cannot assist with decision making within that growing season.

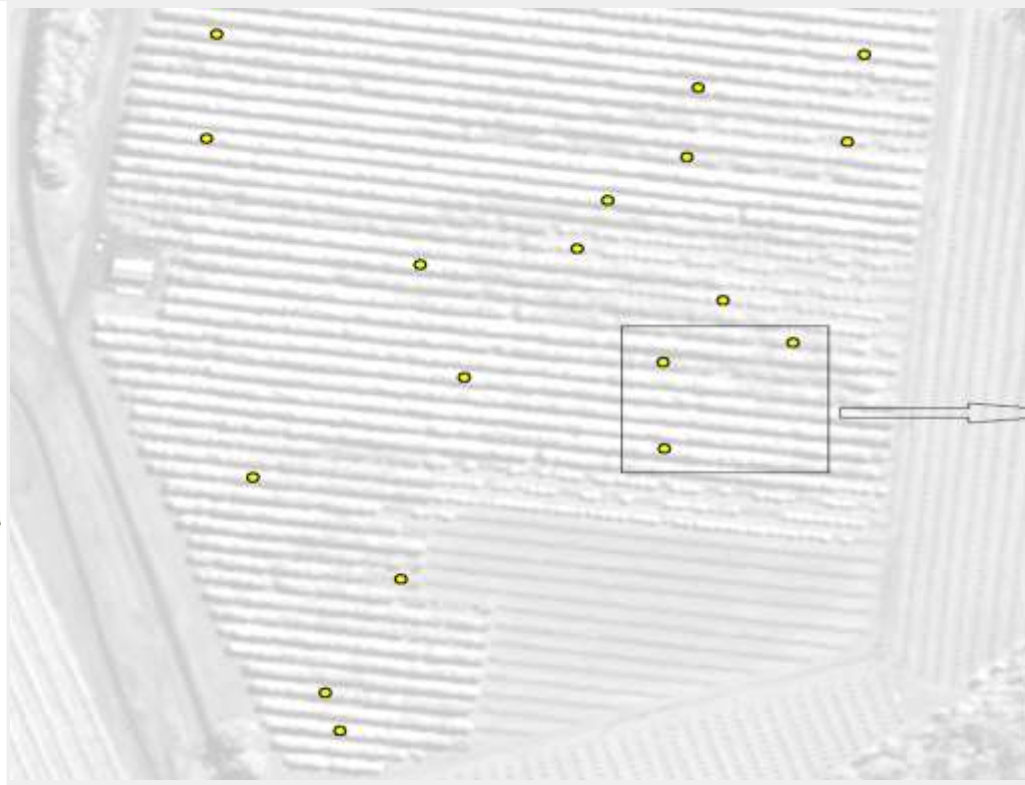




# Remote Sensing Yield forecasting and mapping:



Identify spatial variability of tree health



Extract canopy reflectance of at least 18 trees



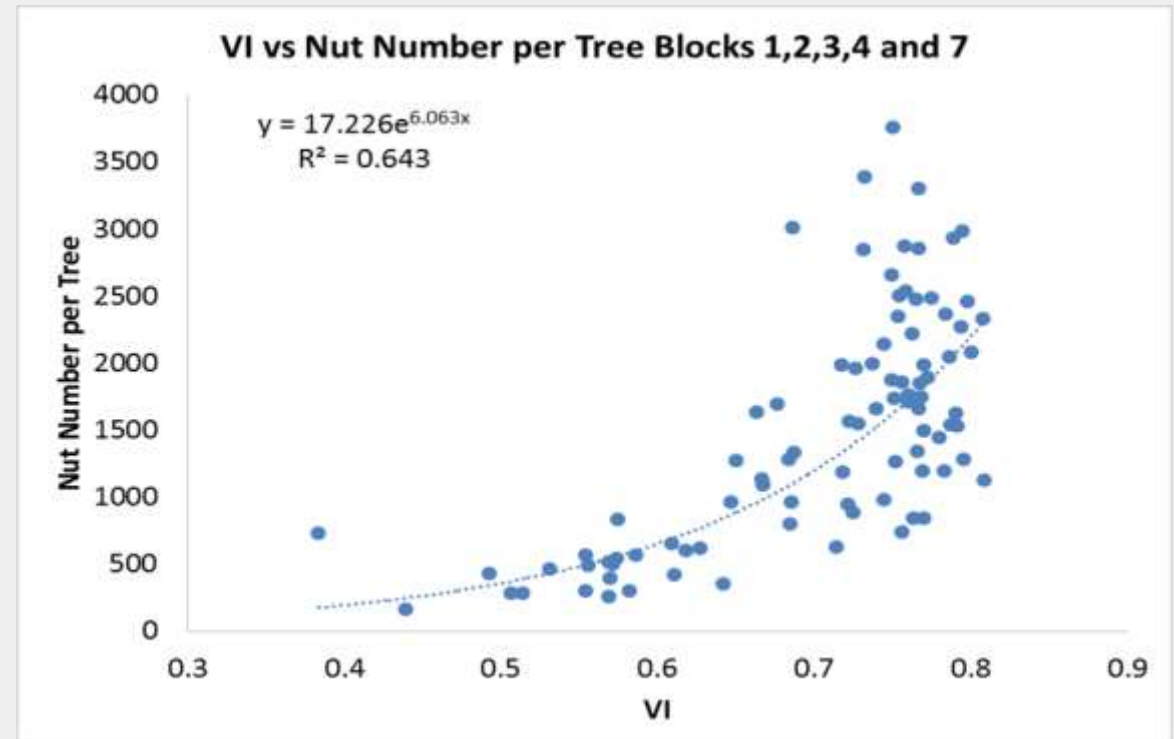
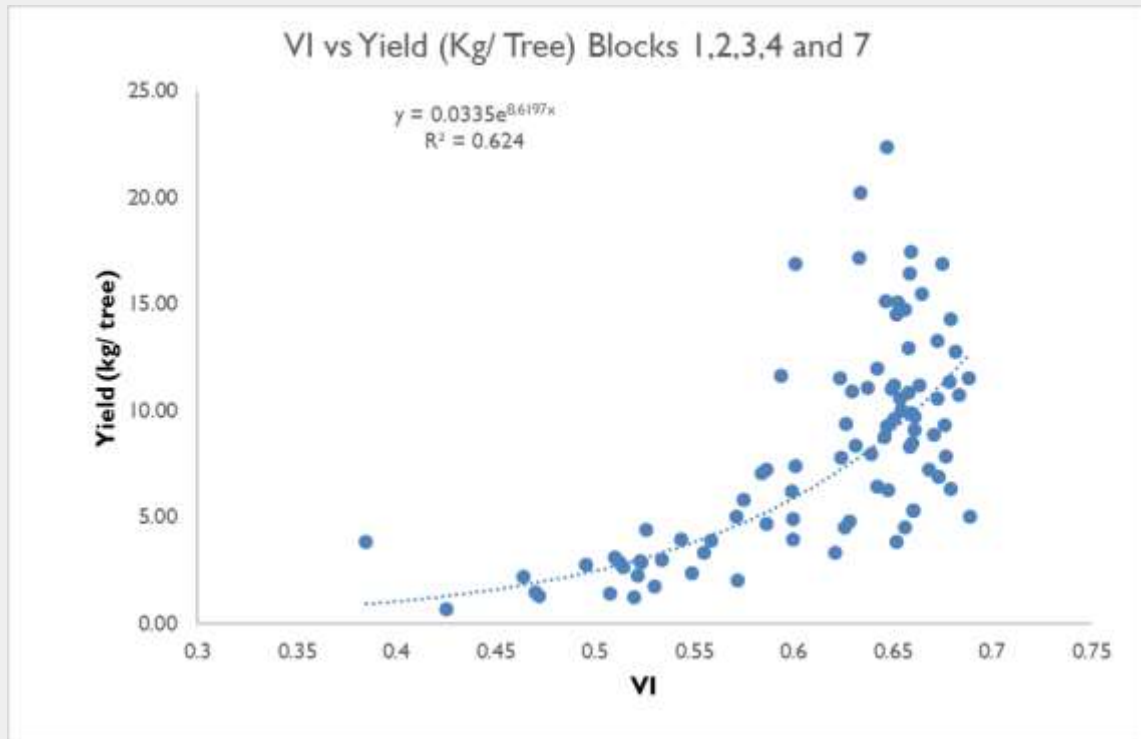
Measure and weigh nuts from the 18 trees



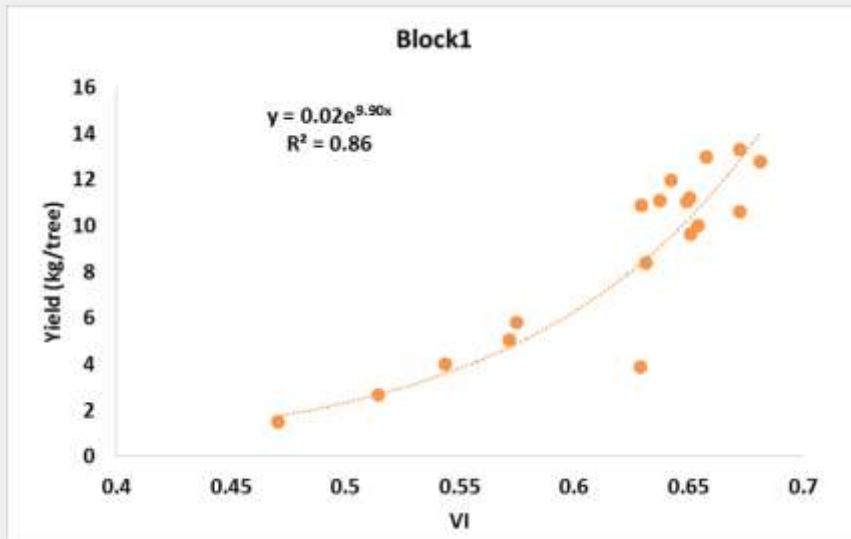
# Yield forecasting and mapping:

Results from 5 macadamia orchards:

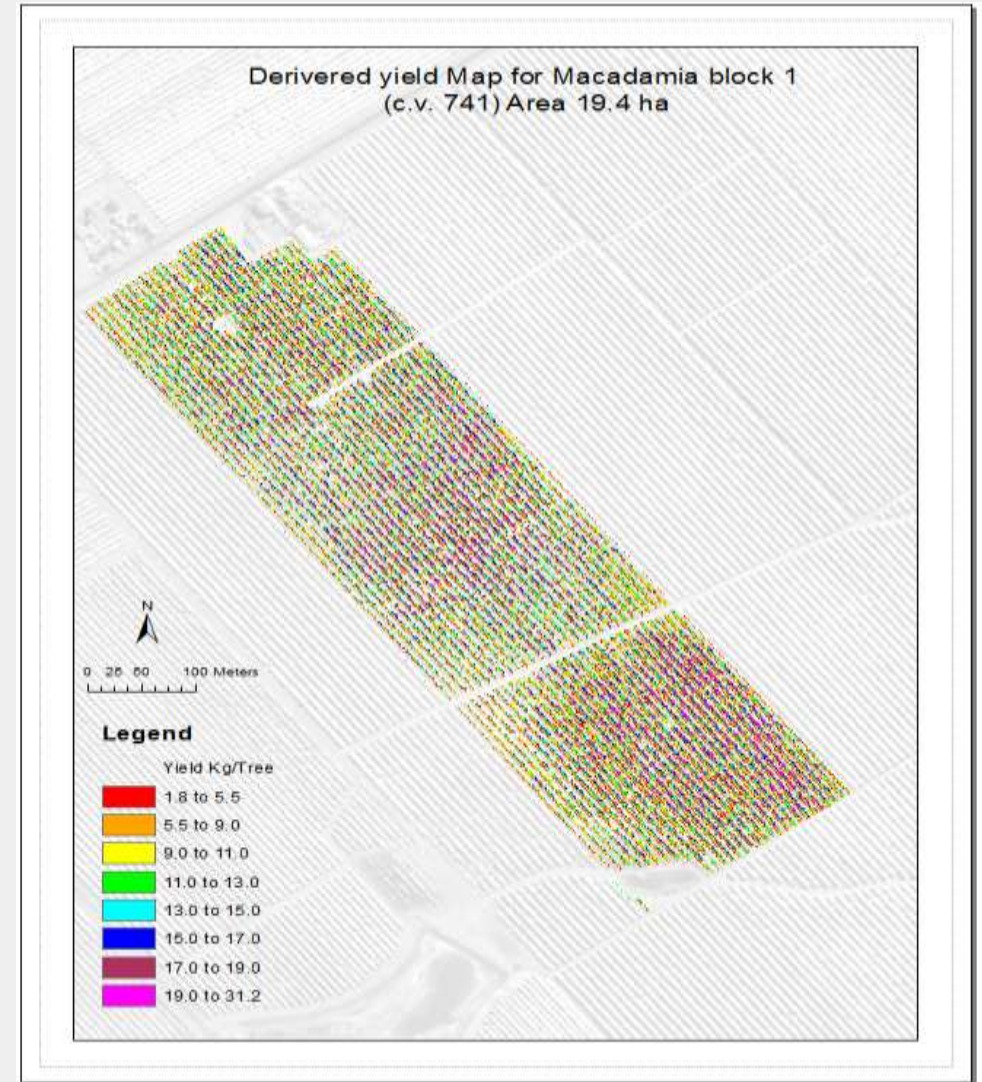
- Tree canopy reflectance (VI) versus individual tree yield (Kg/ha and Nut number per tree).
- Season, location, management and variety do influence the relationships.



# Deriving a Yield Map:

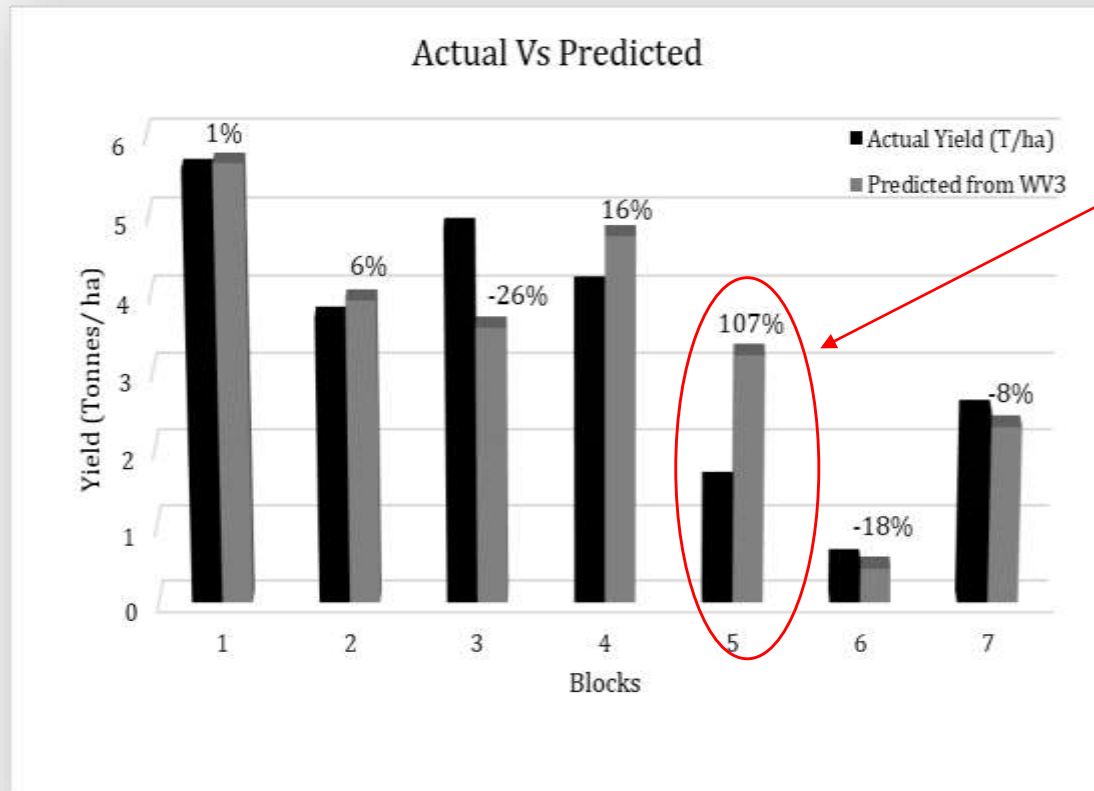


Relationship between yield (kg/ tree)  
and optimal vegetation Index (VI)



Derived yield map (kg/ tree)

# Predict block level yield:



Note \* Block 5 was exposed to an isolated severe storm cell where a significant amount of nuts were washed off the trees.

**This 18 tree method can work for yield, but:**

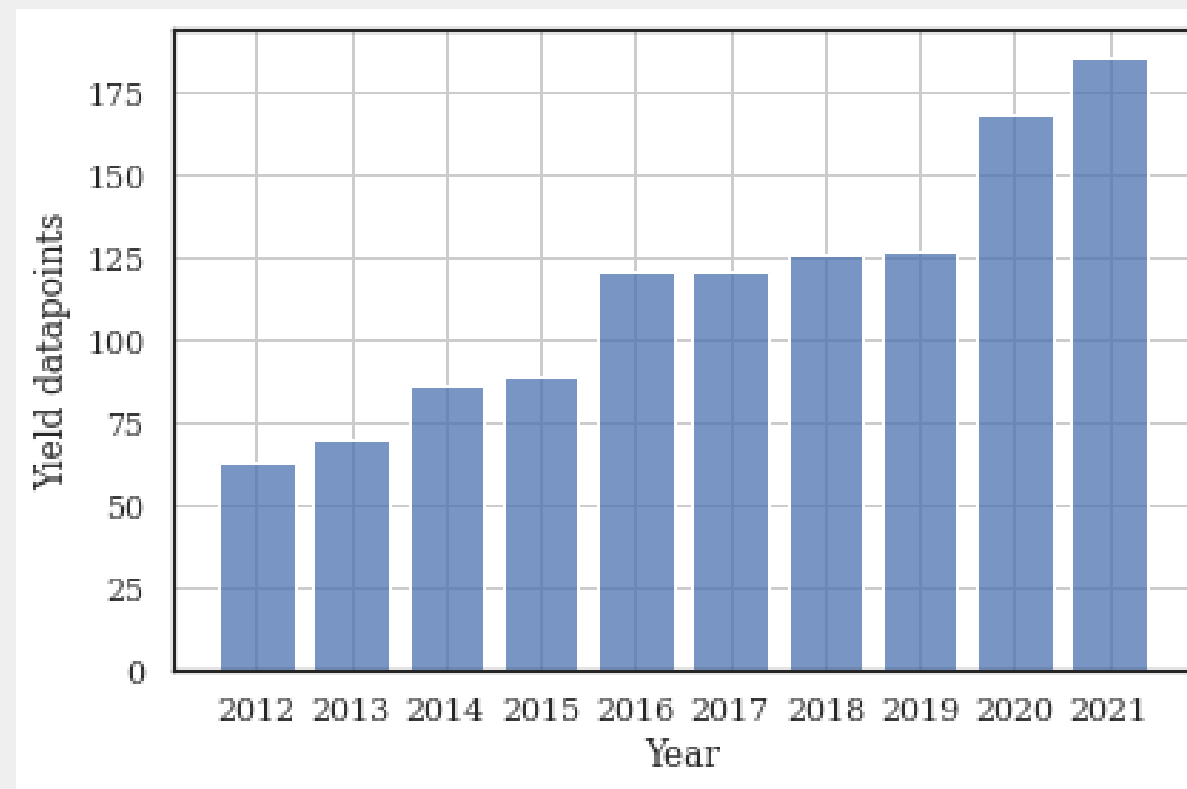
- It is still labour intensive (count nuts from 18 trees).
- Very high resolution imagery can be expensive;
- Maps / predictions again only available at harvest.
- Difficult to scale.

Predicted versus actual harvested yield

# Yield forecasting: 'Time series' / weather data / historic yield / tree age



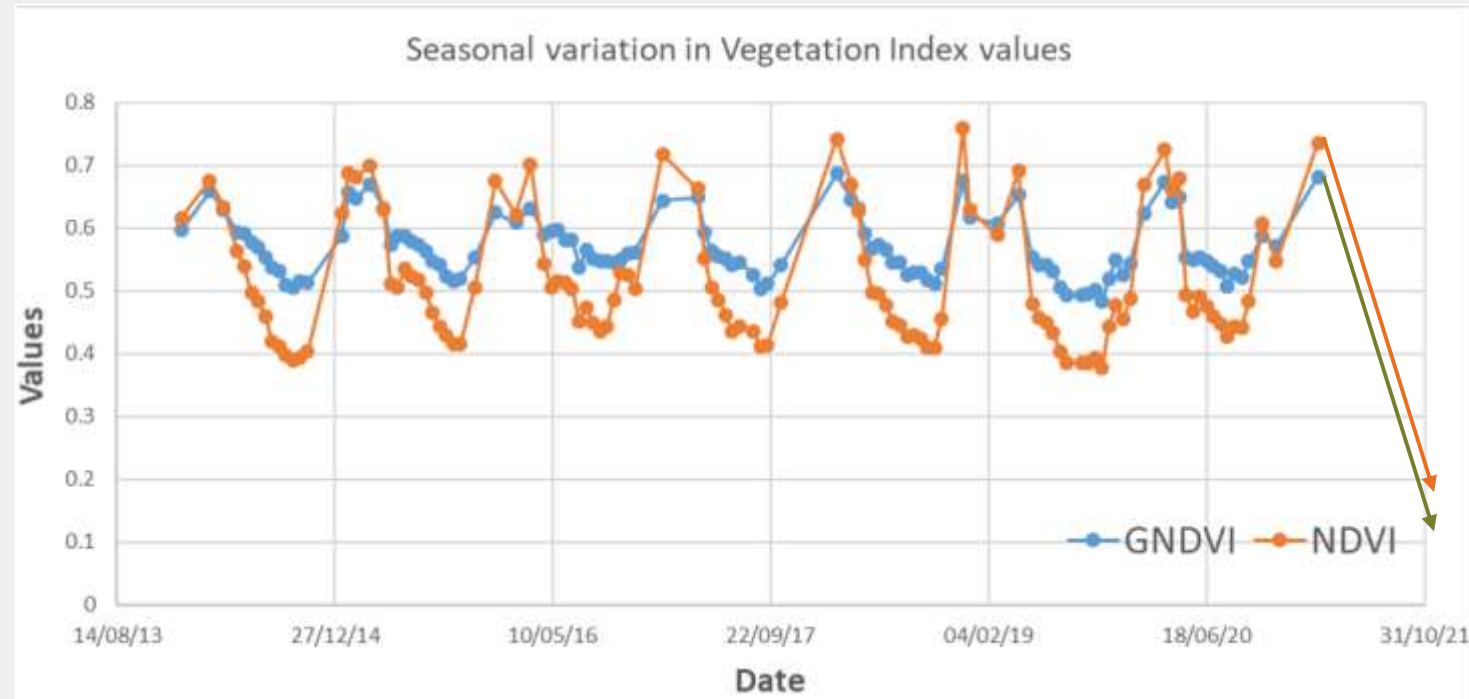
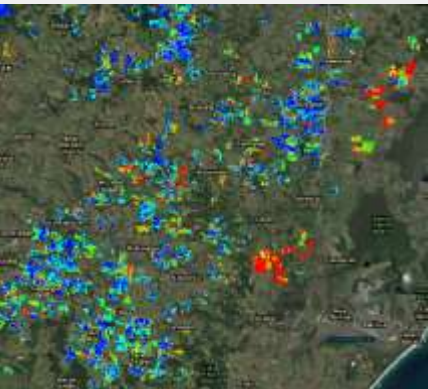
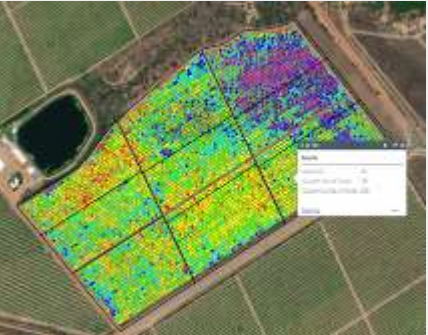
- 4 growing regions
- 1,156 yield records
- 204 blocks
- 21 farms
- 1,800 ha



# Power of monitoring temporal trends:

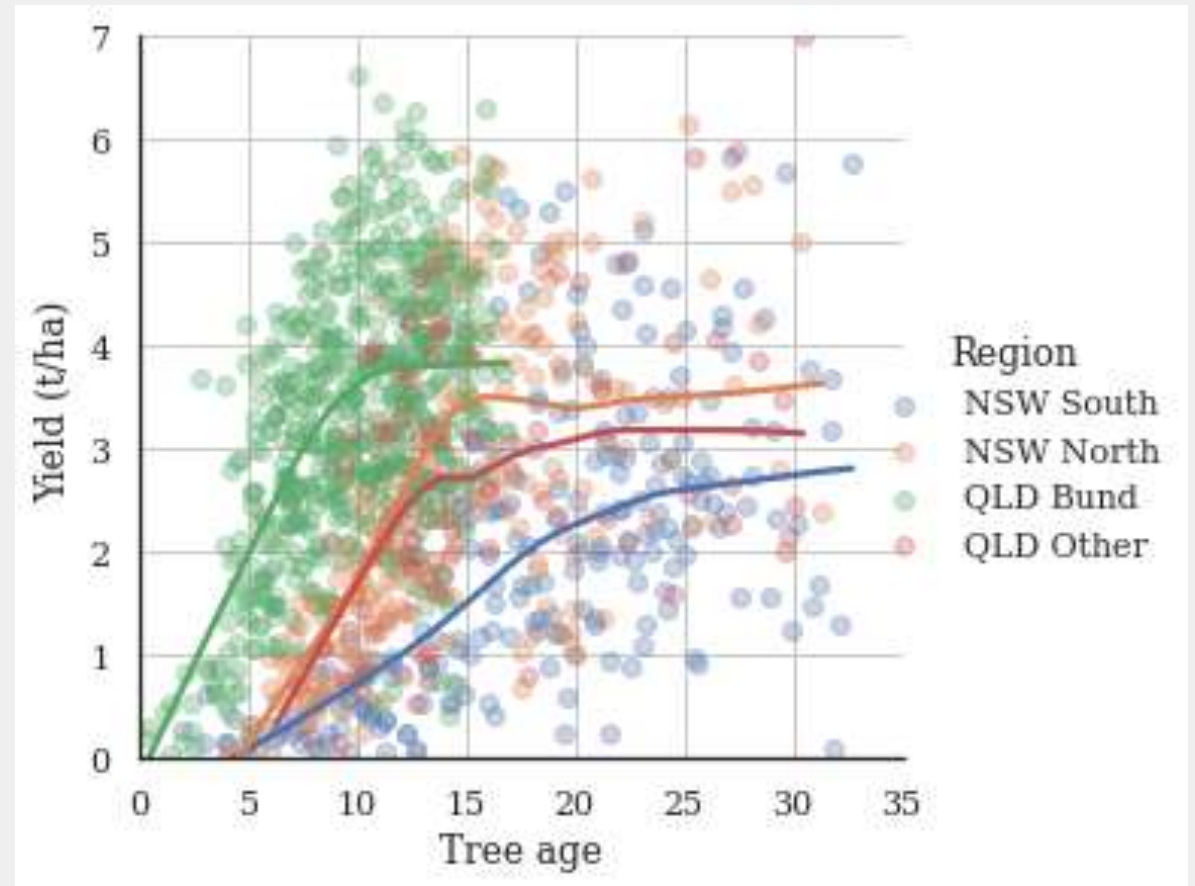
Benchmarking annual growth profiles can indicate:

- Timings of key phenological growth stages.
- Seasonal and long term climate influences.
- On-set of pest and disease incursions.



# Correlation between Yield and Tree Age:

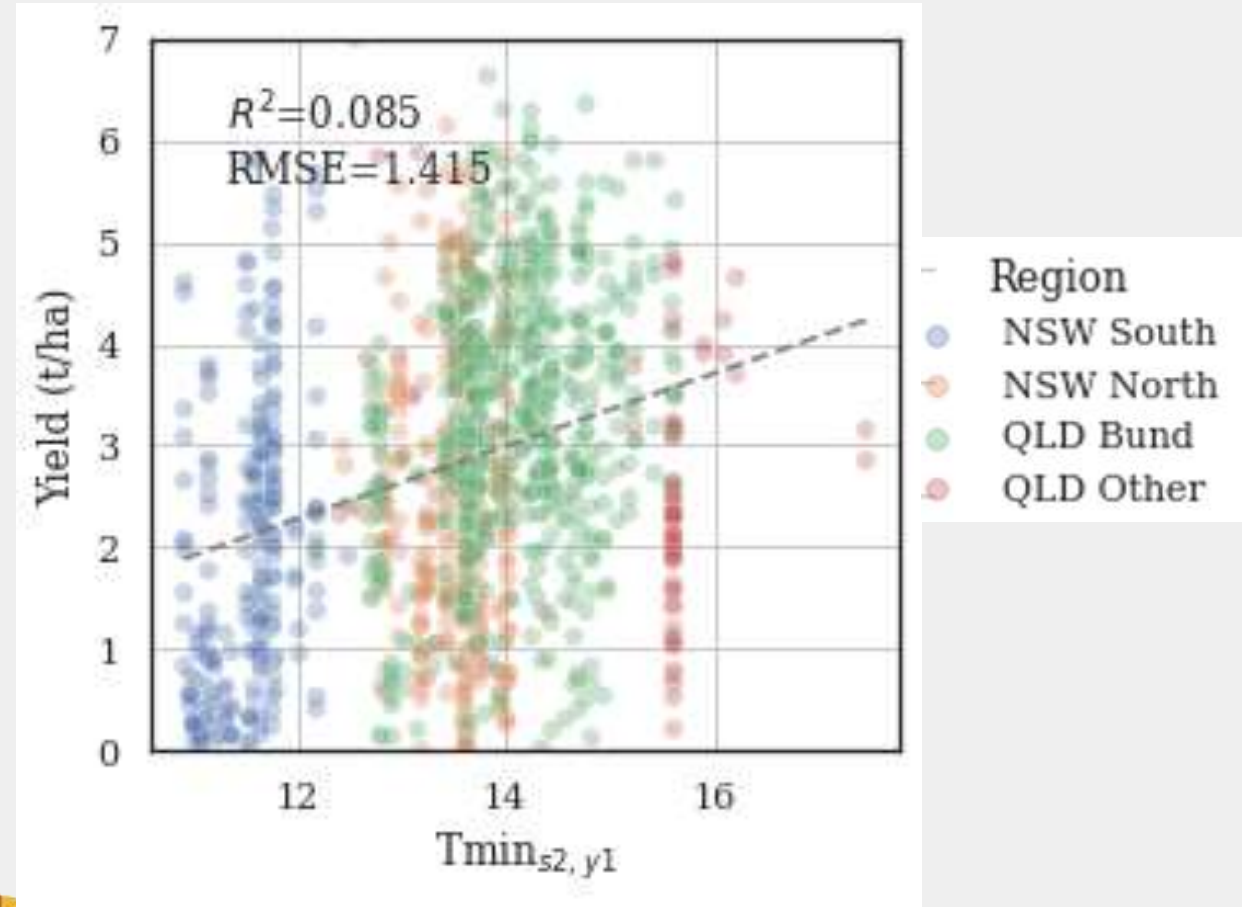
Region	R <sup>2</sup>
NSW South	0.35
NSW North	0.33
QLD Bund	0.24
QLD Other	0.21





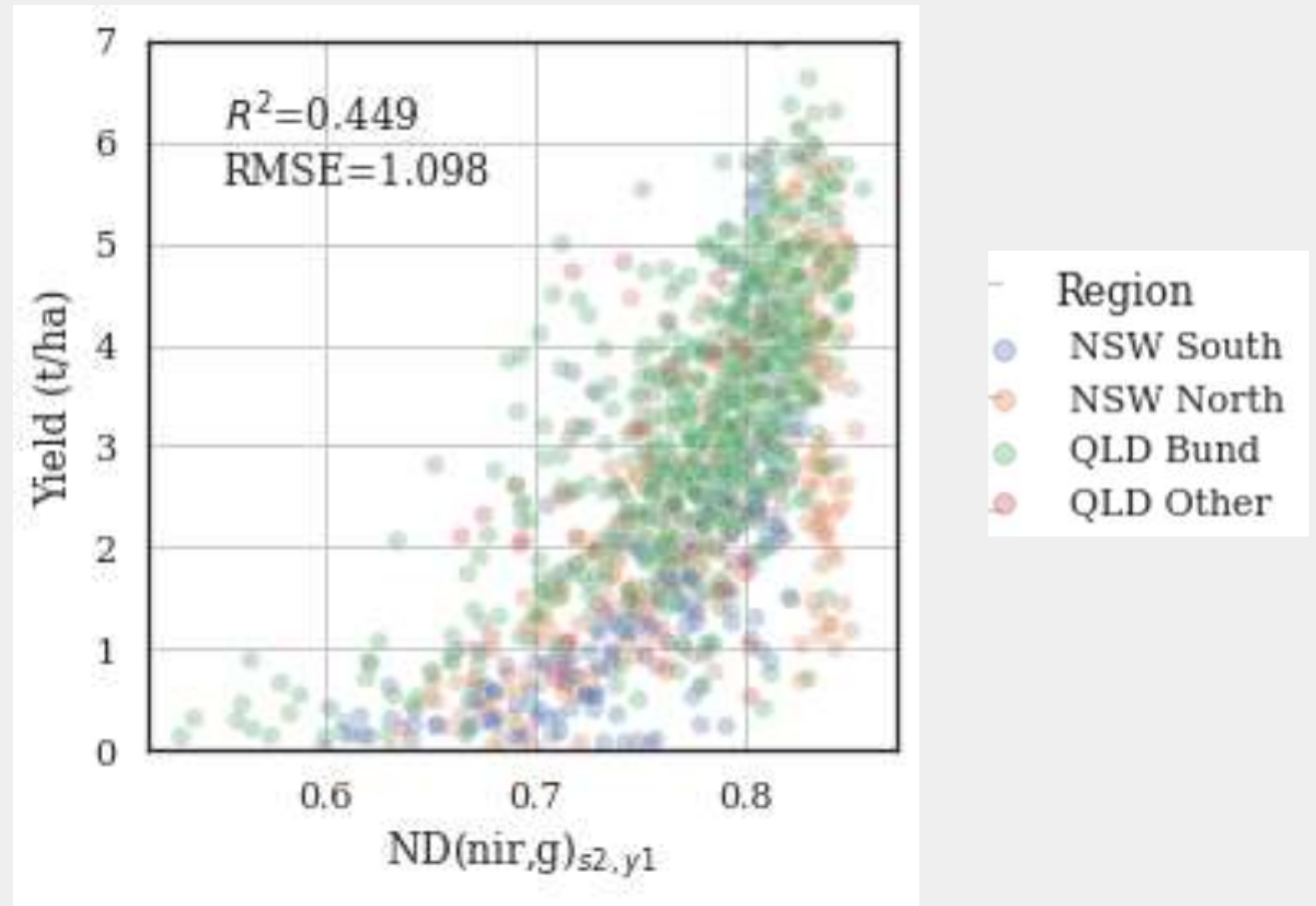
# Correlation between Yield and Weather:

Best weather variable was Minimum Temp.

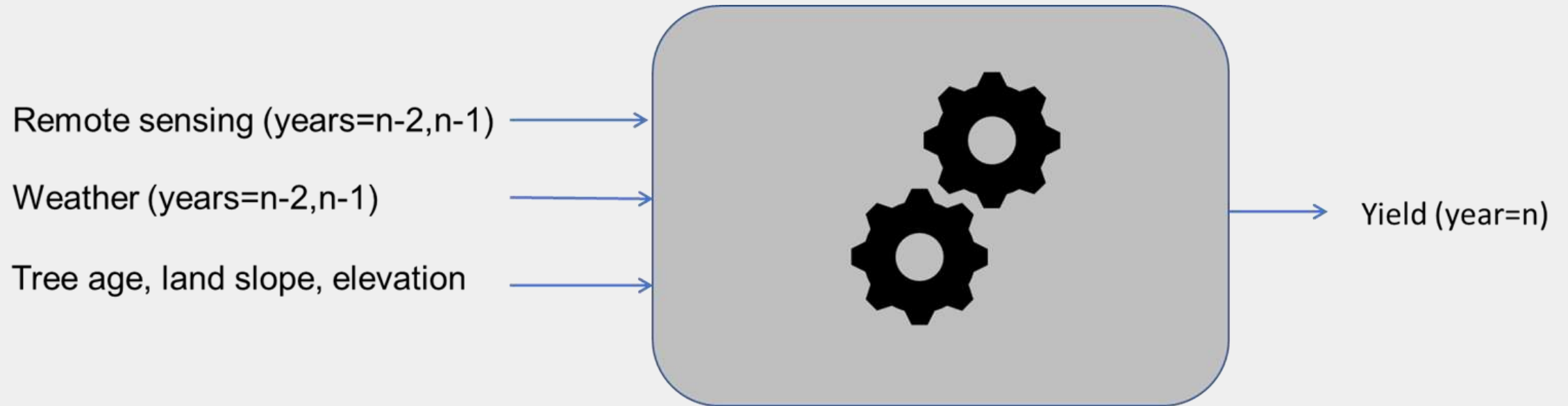


# Correlation between Yield and satellite imagery:

Best Vegetation index was ND (NIR, Green)

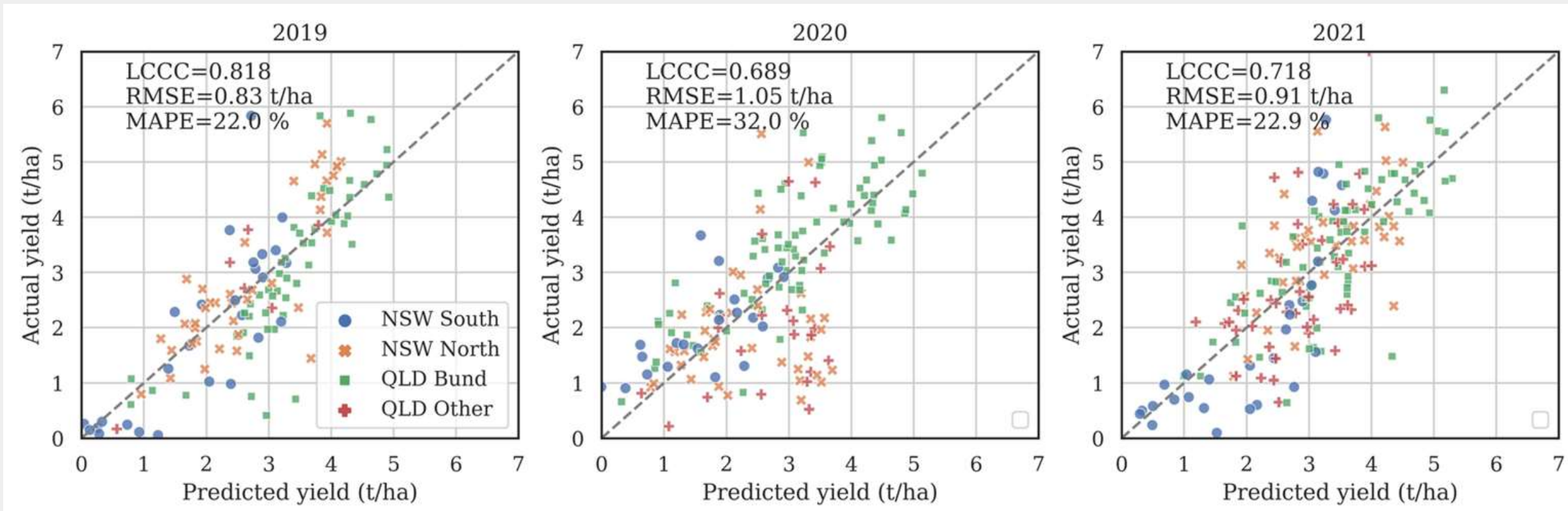


# Time series/ ML Yield forecasting:



# Time series/ ML Yield forecasting:

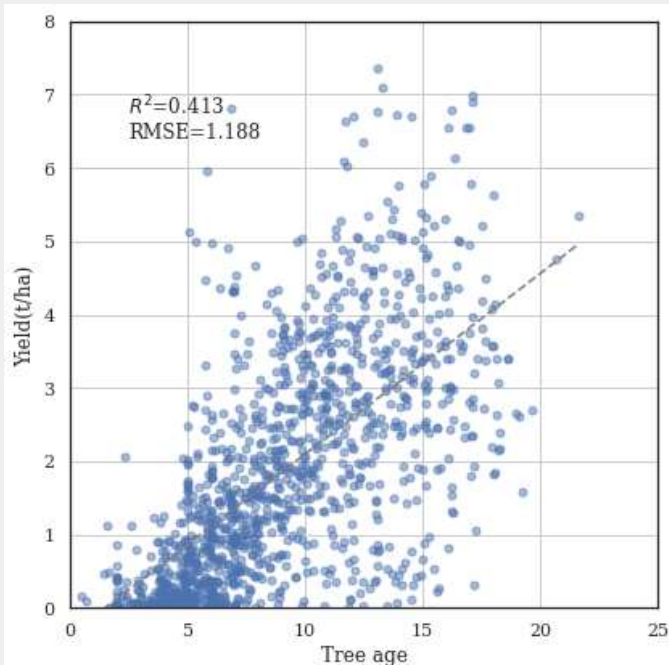
Prediction accuracies at the Block level for the four Australian Growing Regions



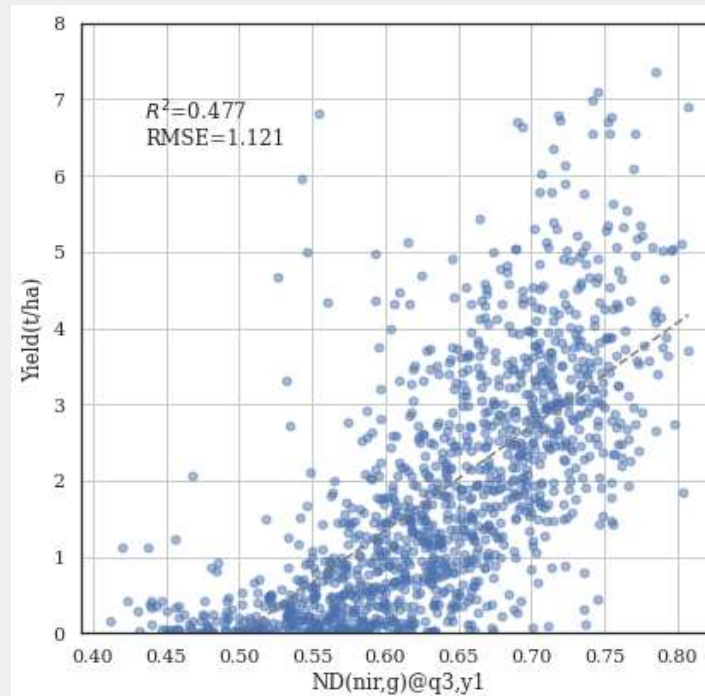
- Lin's concordance correlation coefficient (LCCC) measures how close the predicted and actual yields are to the perfect agreement 1:1 line.
- The root mean squared error (RMSE).
- Mean absolute percentage error (MAPE) is the error normalized to average yield.

# Macadamia Yield forecasting South Africa:

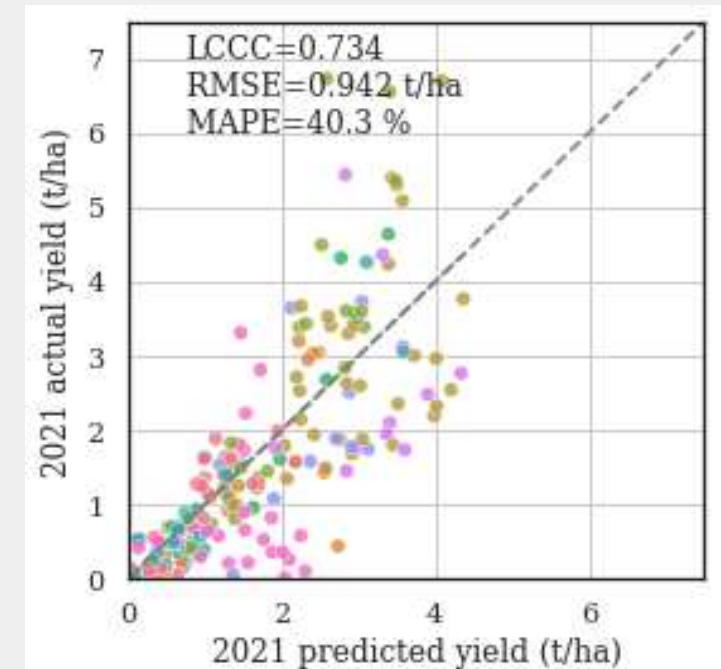
- 320 blocks with a total of 1,267 records from 2011–2021.
- Many of the highest correlated predictors were the same as those found in Australia, with the remote sensing predictors much more significant than weather predictors. The most important weather predictor being minimum temperature.



Correlation between Yield and Tree Age



Correlation between Yield and satellite imagery



Actual versus predicted at the block level (colours indicate different farms)

# Time series / ML Yield forecasting:

Weather data (5km grid)

This method of yield forecasting looking very promising as:

- Does not require in-field sampling;
- Uses freely available satellite data and weather data;
- Can provide forecasts 4–7 months before commercial harvest;
- Highly scalable using the national map of orchards

Brinkhoff, J., Orford, R., Suarez, L. A., & Robson, A. R. (July 2023). Data Requirements for Forecasting Tree Crop Yield-A Macadamia Case Study. In *Precision Agriculture '23* (14<sup>th</sup> European Conference on Precision Agriculture). <https://doi.org/10.3920/978-90-8686-947-3> <https://dx.doi.org/10.2139/ssrn.4443667>

Brinkhoff, J., Robson, A.J., [Block-level macadamia yield forecasting using spatio-temporal datasets](#), *Agricultural and Forest Meteorology*, Volume 303, 2021.

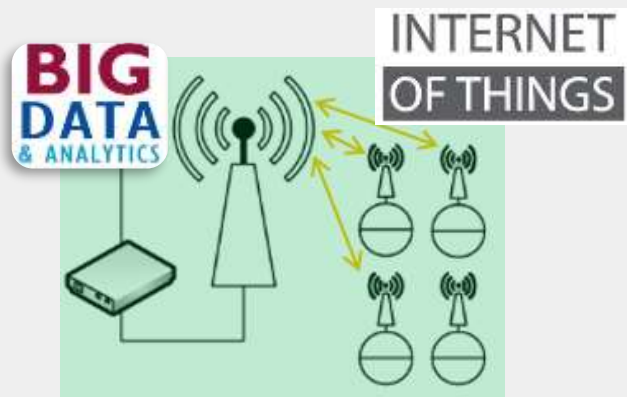
Brinkhoff, J.; Robson, A.J. [Macadamia Orchard Planting Year and Area Estimation at a National Scale](#). *Remote Sens.* 2020, 12, 2245.



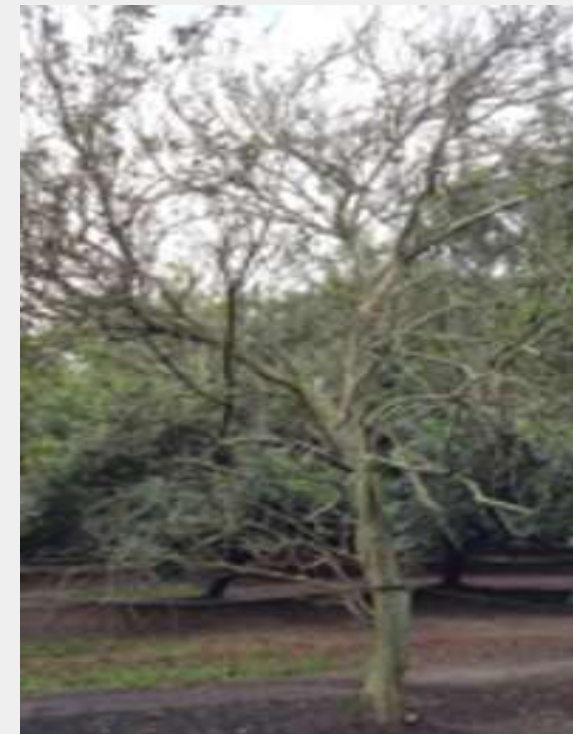
Note: A similar methodology has been tested on avocado in South Africa (SAAGA) and is now being rolled out across 6 countries.

# Macadamia Quality / Pest and Disease:

Measuring micro-climate variability across orchards may help predict and manage quality, pest and disease.



Sensor  
Networks



# Why does measuring canopy variation help:



Hygrochron Temp/ RH sensor

	Category 5	Category 3	Category 1
ave temp	24.7	24.1	23.9
max temp	34.5	32.6	31.4
min temp	18.1	18.3	18.4
ave RH	78.8	80.5	80.9
max RH	100.3	100.0	99.7
min RH	46.9	50.5	53.2

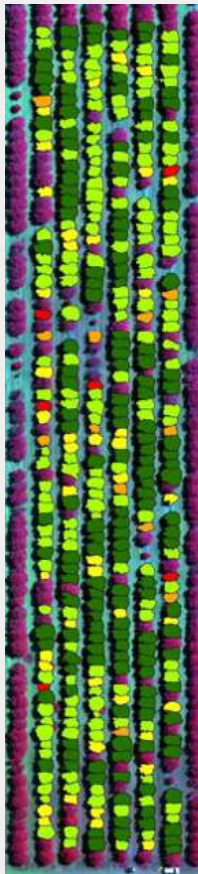
Low vigour trees (Cat 5) had higher average max temp (~3+degC) and slightly lower relative humidity than the High vigour trees (Cat 1).

Temp. accumulation/ critical temps. influence GDD and therefore maturation rate. Supports Harvest timing and Harvest segregation

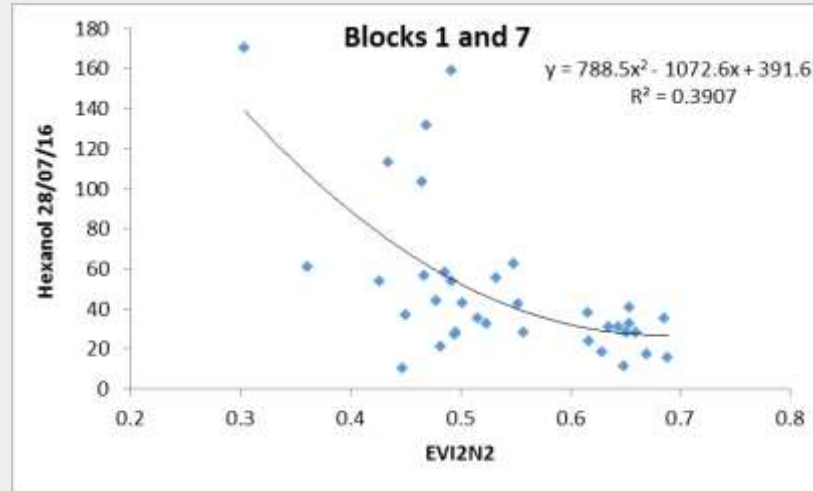




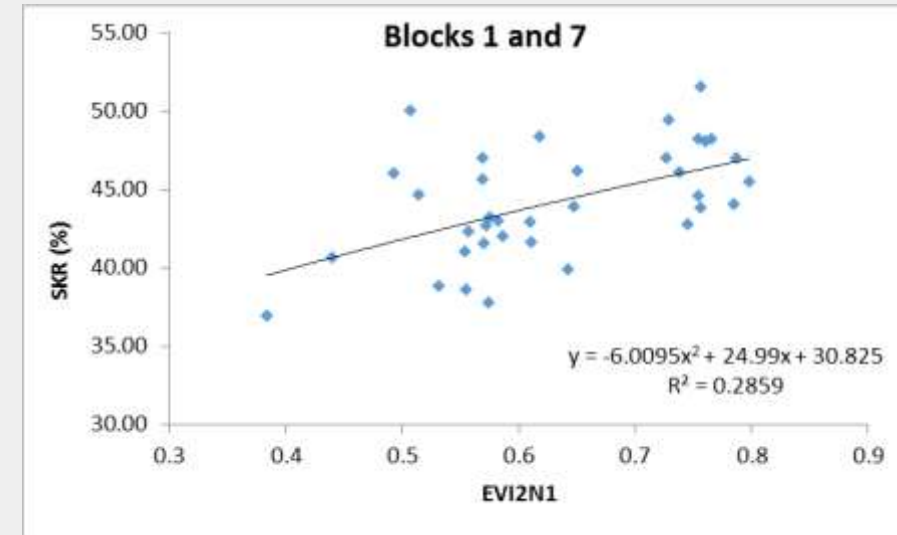
# Canopy reflectance versus nut quality parameters



- Condition 1
- Condition 2
- Condition 3
- Condition 4
- Condition 5

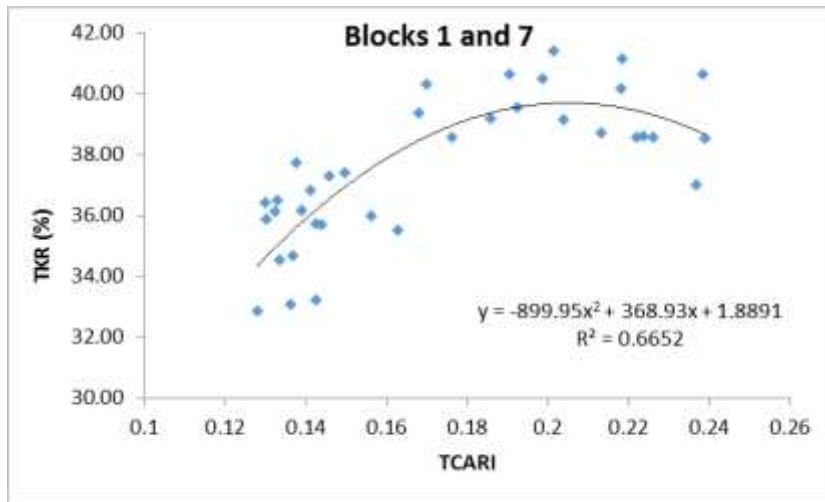
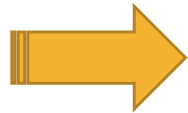
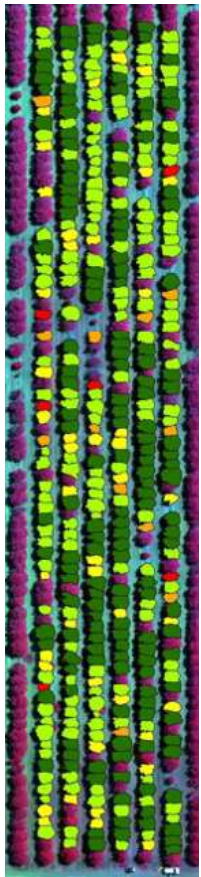


Hexanal: a measure of rancidity, a value of 100 + faint off taste



SKR %: Sound kernel ratio

# Canopy reflectance versus nut quality parameters



TKR %: Total Kernel Recovery: total kernel wt (g)/ nut is shell wt (g) \* 100.

- Condition 1
- Condition 2
- Condition 3
- Condition 4
- Condition 5



## Vapour Pressure Deficit (VPD)

VPD is a climatic variable that can be calculated from relative humidity and temperature (mean and maximum).

Low VPD, plants are susceptible to rot and disease.

High VPD leads to lower photosynthesis and lower yields and hypothesized to lower TKR%.



Cat1: Diurnal temp of 16.5°C

Cat 5: Diurnal temp of 13°C



# Wrap Up



- There are many promising AgTech options currently available to macadamia growers. However, it is the application that best dictates which is best suited...



- Only believe half of the hype of AgTech, and **always** request actual evidence of prior adoption and/or validation...



- If it doesn't produce outputs that exceed commercial practice, is impractical or expensive to adopt, then don't use it...



- Future evolution of AgTech requires communication, collaboration and coordination between industry, researchers and commercial providers.



# Acknowledgements

Thank you to Macadamias South Africa (SAMAC) for the opportunity to present at this congress.

Also the Australian Government Department of Agriculture, Agriculture and Water, Horticulture Innovation and Australian Macadamia Society for funding and supporting much of the research and the many participating growers and industry groups.

A big thank you to Chris Searle, the biggest nut of them all 😊

**Hort  
Innovation**





# QUESTIONS ?

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