Are pulses really more variable than cereals?

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An Australia-wide analysis of within-field variability

Patrick Filippi

Lecturer in Precision Crop Management

Tom MacPherson
Dhahi Al-Shammari
Tom Bishop

Image: Sally Poole

Introduction to pulses in Australia

- Pulses are under-utilised in Australia (e.g. chickpeas, lentils, lupins)
- Pulses are critical for sustainable food production
  - biological nitrogen fixation
  - disease break for cereals
  - alternative source of protein
- Perception that pulses are more variable and riskier than cereals
- This is corroborated by the literature at country/region level, but not within-field
- Sample sizes of within-field data reported for pulses are small
- **Grant:** Mapping yield gap and yield variability in commercial pulse crops (UOS2204-005RTX)

9%
of cropland is sown to pulses

15
pulse yield maps identified in the literature

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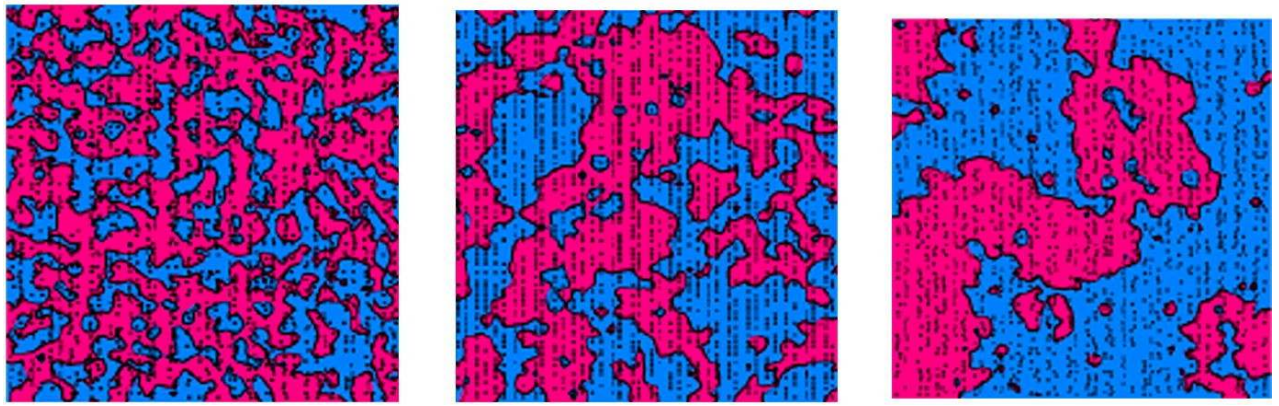
How do we assess within-field variability?

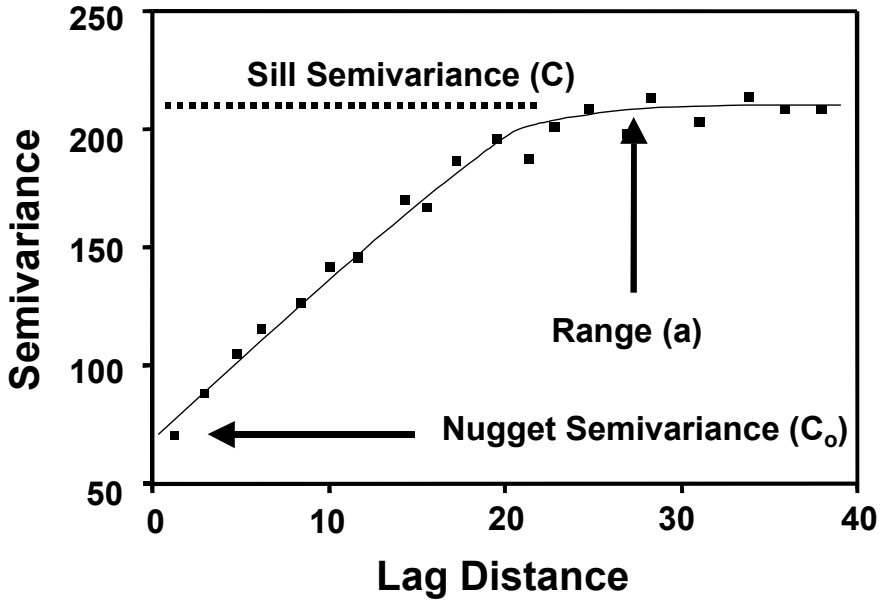
- Typical (non-spatial) statistics to assess variability
  - Variance, coefficient of variation (CV)
- These non-spatial statistics have limitations to evaluate within-field variability
- Example: All 3 fields below have same mean and CV despite having three distinct spatial structures
- Right field is much more amenable to variable rate applications – well-defined spatial structure
- So not just about how variable the field is, but how great the opportunity is for site-specific crop management (SSCM)



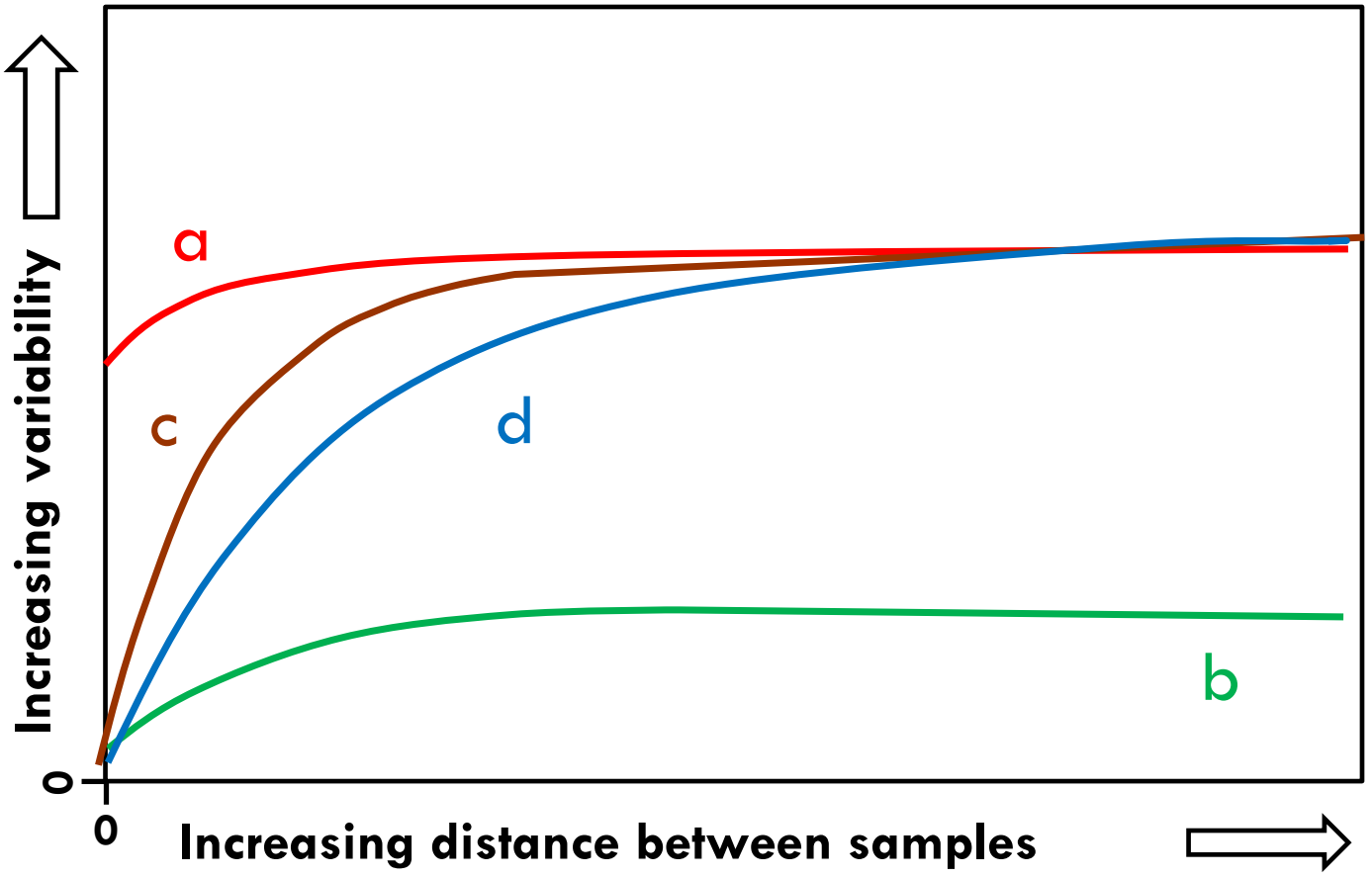
Leroux & Tisseyre (2019)

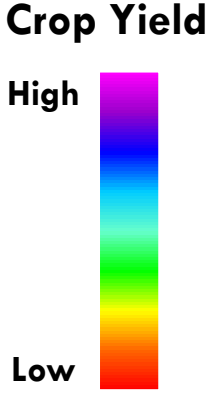
Semivariogram – a model of within-field spatial variability

- We need spatial statistics to assess variability
  - Use semivariogram parameters
- Semivariogram: a model of spatial autocorrelation of data
- Spatial dependence: observations closer are more similar than those further apart
- **Nugget**: Variability at very small distances (measurement error/spatial variation at scale finer than the sampling resolution)
- **Sill**: Plateau/max value reflecting total variance of the data
- **Range**: Distance over which spatial correlation is significant, beyond this range, data points are considered uncorrelated



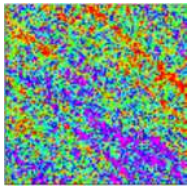
Semivariogram – a model of within-field spatial variability





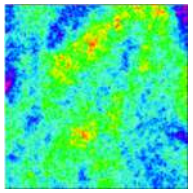
Large variance / poor structure

a



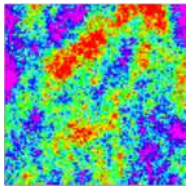
Small variance / moderate structure

b



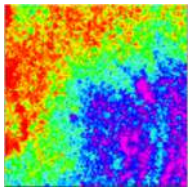
Large variance / moderate structure

c



Large variance / strong structure

d

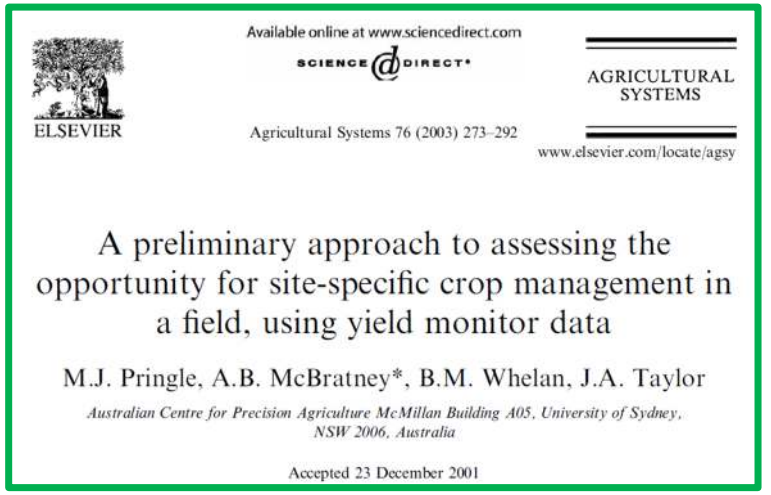


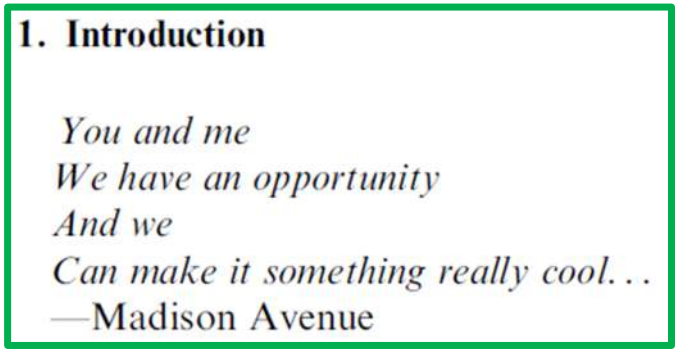
Opportunity Index (OI)

- Considers non-spatial variation, spatial variation, machine constraints to variable rate
- The opportunity for adopting variable management

$$OI = \sqrt{M_v \cdot S_v} = \sqrt{\frac{CV_a}{q_{50}(CV_a)} \cdot \frac{C}{O}}$$

- M_v = magnitude of variation, S_v = spatial structure of variation
- CV_a = magnitude mean semivariance field – nugget
- $q_{50}(CV)_a$ = median CV_a across all fields
- C = correlation distance – range parameter
- O = minimum operation distance of machinery





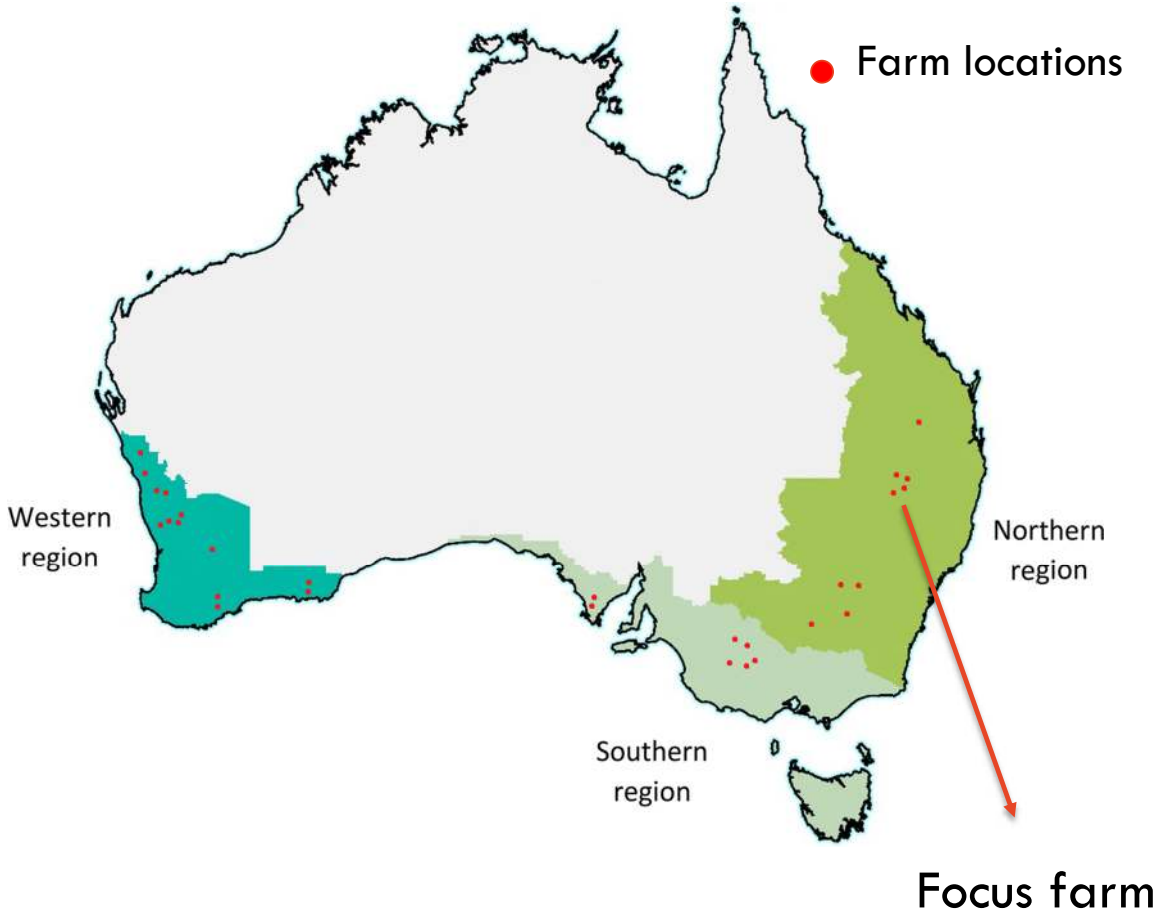
de Oliveira, R. P. (2009). Contributions towards decision support for site-specific crop management - A study of aspects influencing the development of knowledge-intensive differential management decisions. PhD Thesis. The University of Sydney, Sydney, Australia.

Aims of the study

- Collate large yield database of pulse and wheat crops across Australia
- Compare difference between pulse and wheat crops across Australia in terms of (i) coefficient of variation and (ii) opportunity index
- Present this information meaningfully to growers/advisors (classification of results into, low, medium, high opportunity)
- For a focus farm examine (i) difference between pulses and wheat (ii) temporal stability of opportunity index

Study dataset

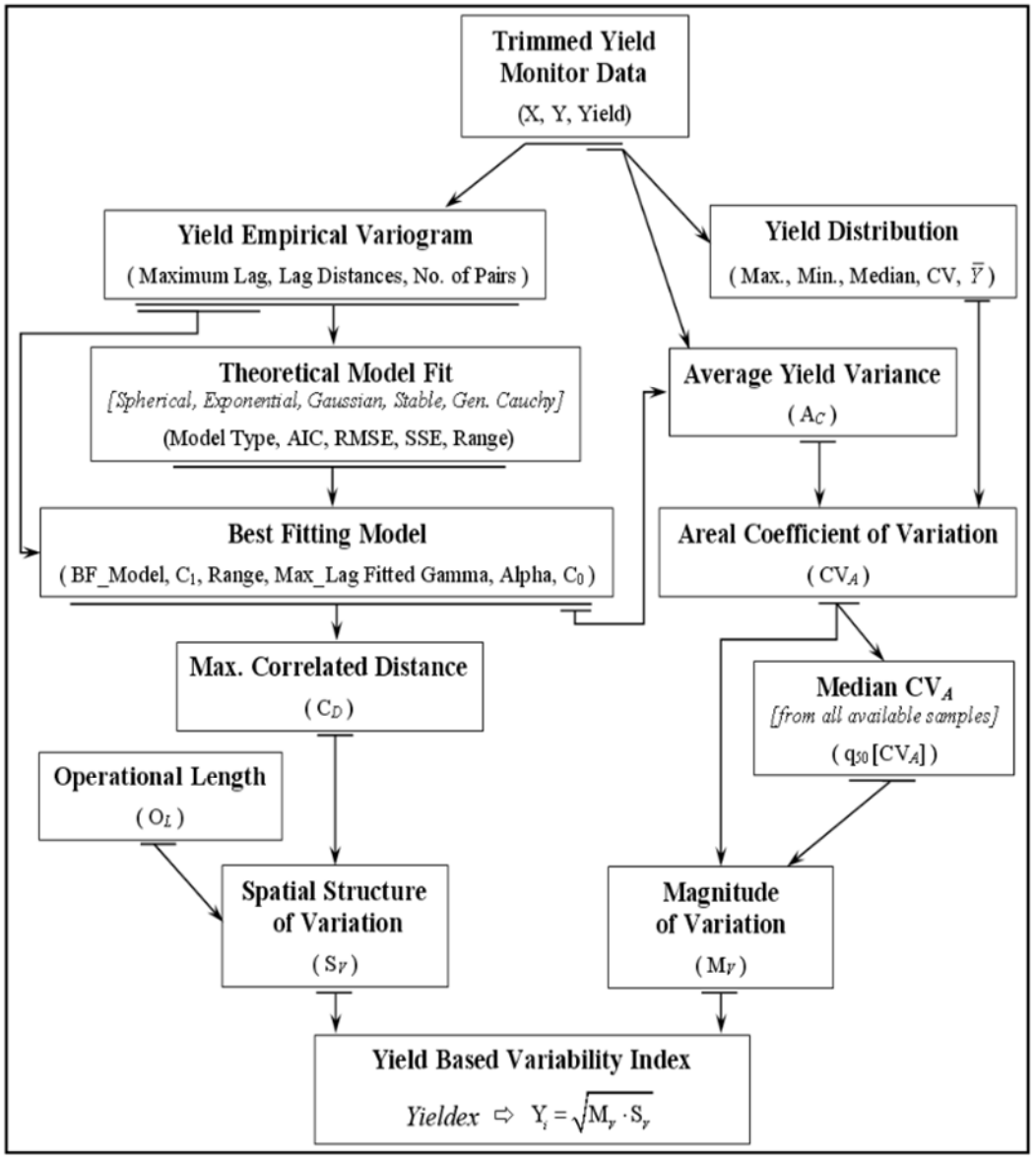
- 885 yield maps
- 29 farms
- Between 2009-2022
- Four crops
  - Chickpeas (n = 203)
  - Lentils (n = 68)
  - Lupins (n = 150)
  - Wheat (n = 464)



Methods

Calculation of Opportunity Index (OI)

Source: de Oliveira, R. P. (2009). *Contributions towards decision support for site-specific crop management - A study of aspects influencing the development of knowledge-intensive differential management decisions*. PhD Thesis. The University of Sydney, Sydney, Australia.



Results – Nationwide analysis

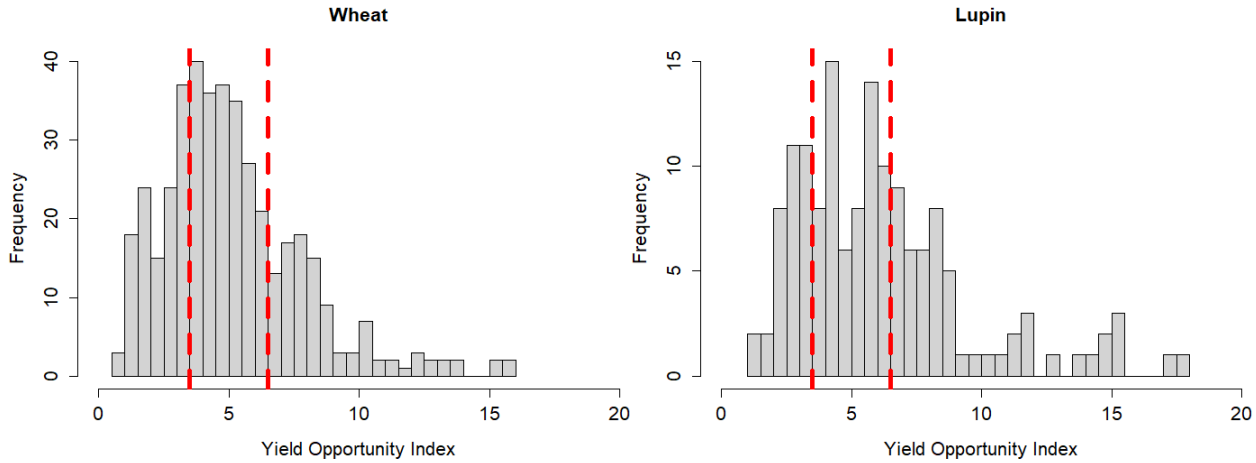
Species comparison

- Opportunity index (OI) varied from 0.86–17.78
- No clear difference between species
- Rankings differed between coefficient of variation (CV) and OI

Species	Mean CV (± SD)	Mean OI (± SD)
Chickpea	0.29 (± 0.15)	5.63 (± 2.87)
Lentil	0.29 (± 0.1)	4.34 (± 2.65)
Lupin	0.39 (± 0.16)	6.13 (± 3.38)
Wheat	0.26 (± 0.15)	5.12 (± 2.73)

Classification of OI

- Split the data by 1st & 3rd quartiles
- Low opportunity < 3.5, High > 6.5
- Threshold of 6 previously suggested



Methods – Focus farm analysis

Study area

- We examined a 7,000 ha farm in Northern NSW
- 32 fields, total of 172 yield maps

Species comparison

- Results of OI for chickpea and wheat fields from 2009-2022 were aggregated and compared
- Comparison of species in lower (2016) and higher (2020) rainfall seasons

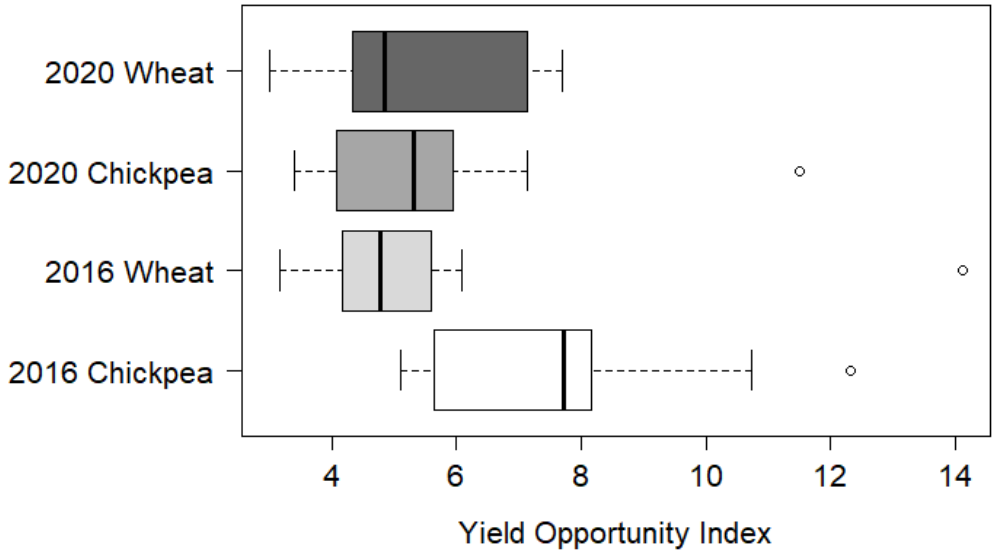
Behaviour of OI

- Representative maps for low, medium, and high opportunity identified
- If a field was in the same class in $\geq {}^{2}/_{3}$ seasons, it was deemed stable

Results – Focus farm analysis

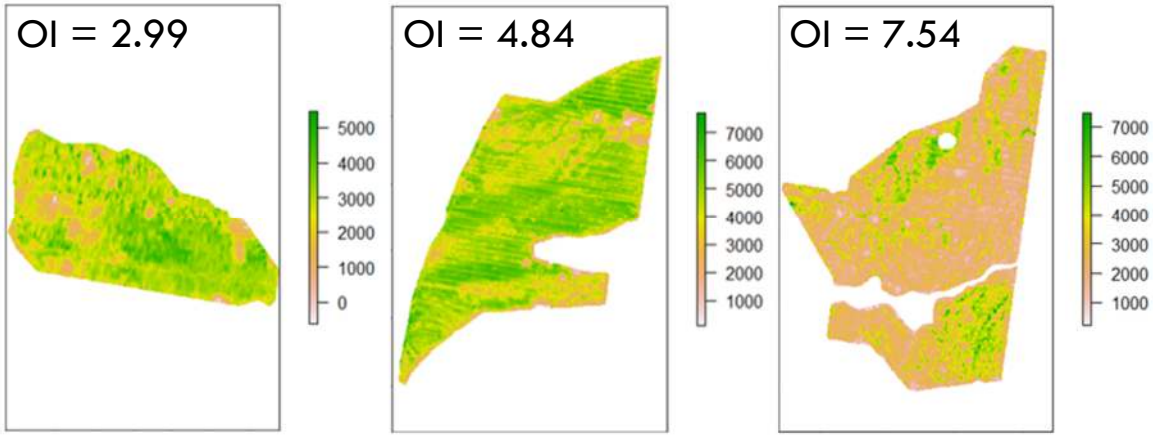
Species comparison

- Difference between wheat and chickpea varied depending on the season
  - larger difference in 2016 compared to 2020
  - 2020 was a wet year



Classification

- Yield maps of low, medium and high OI
- More coherent zones with larger differences in yield were observed as OI increased



Yield Maps

Results – Focus farm analysis

- Opportunity Index classified based on 1st and 3rd quartile for all yield maps across Australia

Classification	Low	Medium	Low
Opportunity index	<3.5	3.5-6.5	>6.5

- Stability: stable if it exhibited the same classification in greater than or equal to two thirds of the available seasons for that field (n = 32 fields)

	High	Medium	Low
Stable	2	8	0
Unstable	12	5	5

Discussion – Classification of OI & grower implications

What can a grower do with this?

- Rank their fields by opportunity for SSCM
- Determine immediately if a field warrants further investment for SSCM
- Intuitive zones are clear in high opportunity fields
- Critical outcome for gradual adoption
- Example: a grower could increase inputs in high yielding zones for drier years
- Better management of variability has numerous benefits: environmental, economic

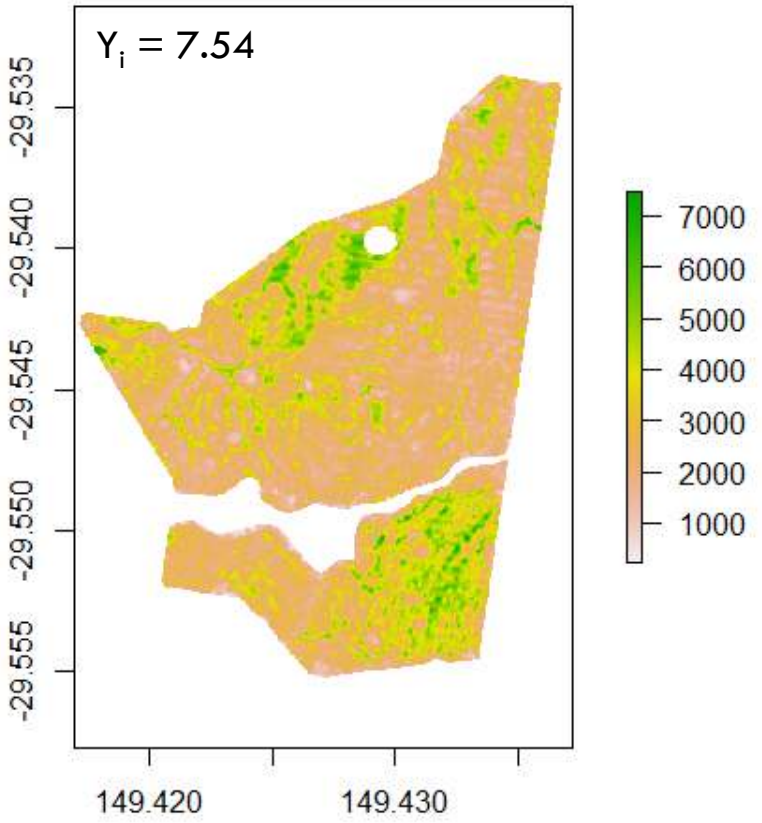


Figure 6

Discussion & Conclusions

Look... If you had... one shot... or one opportunity...
To seize everything you ever wanted... one moment...
Would you capture it? Or just let it slip?
Yo
Marshall Mathers

Pulses vs Wheat

- OI results suggested that manageable variability is similar between species
- CV may indicate that pulses are more variable than wheat (masks the impact of spatial structure)
- Pulses may not be as risky as growers think, but other factors may lead to less pulses being sown

Behaviour of OI

- Some temporal fluctuation in OI for certain fields, which causes uncertainty in decision making
- Focusing on high opportunity and more stable fields is a good starting point for PA

Classes

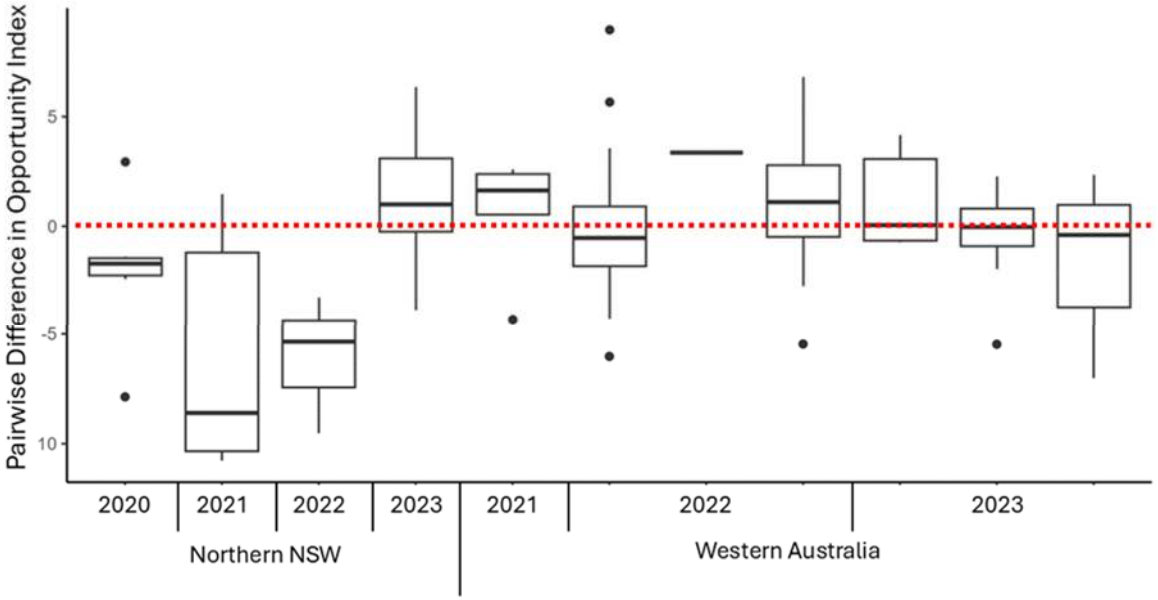
- Establishment of thresholds allows growers to begin the SSCM process more easily and begin to optimise their system

Future work

- Scale this analysis up
- More single farm comparisons to look for farm and region-specific differences in opportunity for pulses and cereals
- Verify OI with on-farm experimentation, hypothesis that high OI will have a spatially variable and strong yield response
- Benchmark OI with growers and agronomists
- Predict and forecast OI using data-driven models and wealth of spatial-temporal datasets

OI of managing grain protein content – how does this compare to yield?

- Uptake of harvester-mounted protein sensors increasing
- Two farms assessed – Northern NSW and WA
- Calculated OI for both wheat yield and grain protein content (GPC) - figure shows difference between these (Yield OI – Protein OI)
- Results show there is a greater opportunity to manage GPC than for yield in northern NSW (mostly negative values)
- Generally, appears to be a greater opportunity to manage for yield compared to GPC in WA
- Future work in scaling this up, but understanding the causes of these differences – soil types, temporal variability in weather etc.



Negative values = greater opportunity for managing protein
Positive values = greater opportunity for managing yield


Questions?