A comparison of different within-trial analysis approaches to spatial variation

Joint work with Adrian Roberts and Ian Nevison

Acknowledgements: AHDB (Cereals and Oilseeds) & BSPB.

Overview

- Background
- Potential within-trial models
- Assessment methodology
- Available datasets
- Results
- The wider context
- Conclusions

The key objectives

Evaluating spatial modelling options in variety trials

Explore potential for variety comparisons **in UK context**

Magnitude of improvements in **within-trial** model?

Magnitude of improvements in **over-trials** precision?

Practicalities:

Routine application

Securing buy-in of **stake-holders**

Background (1)

Prior to late 1970's – Randomized complete blocks

Advance: **α – lattice designs**

Improved precision = **less** replication needed within trial

Fixed = Variety **Random = Rep/Block**

Background (2)

Analysis of α – lattice designs

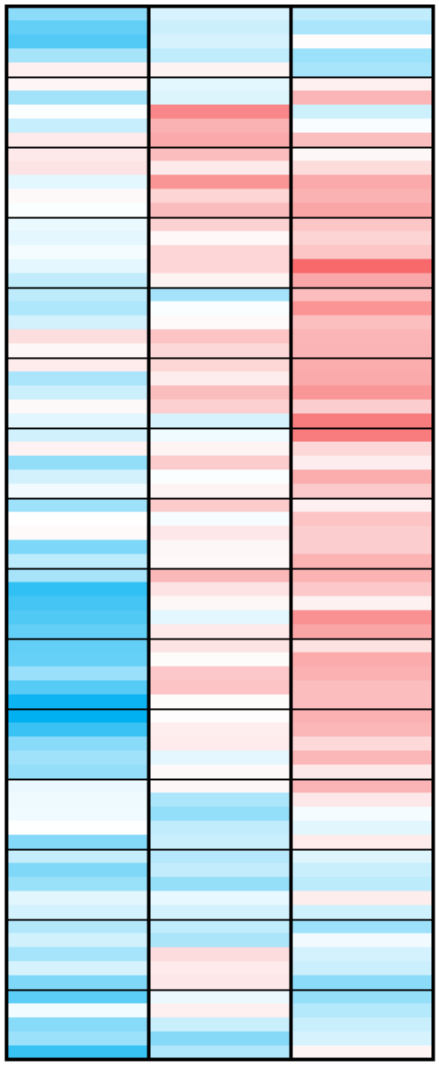
Fixed = Variety **Random = Rep/Block**

Aim: Modelling an approximation to underlying trends

Modelling trends as a **step** function of **block** effects

Adjusting for block-to-block differences

Not adjusting for trends **within** blocks



Background (3)

α – lattice designs & associated analysis

Adopted for the last 40 years in UK context

Easy to apply routinely

Choice of model predetermined by design

Background(4)

Spatial analysis of variety trials – Topic of research for many years

Australia has led the way - methodological developments
- application

Papers such as Gilmour, Cullis and Verbyla (1997) and Verbyla (2019).

We're operating in a **different** context to Australia's.

Individual trial layouts

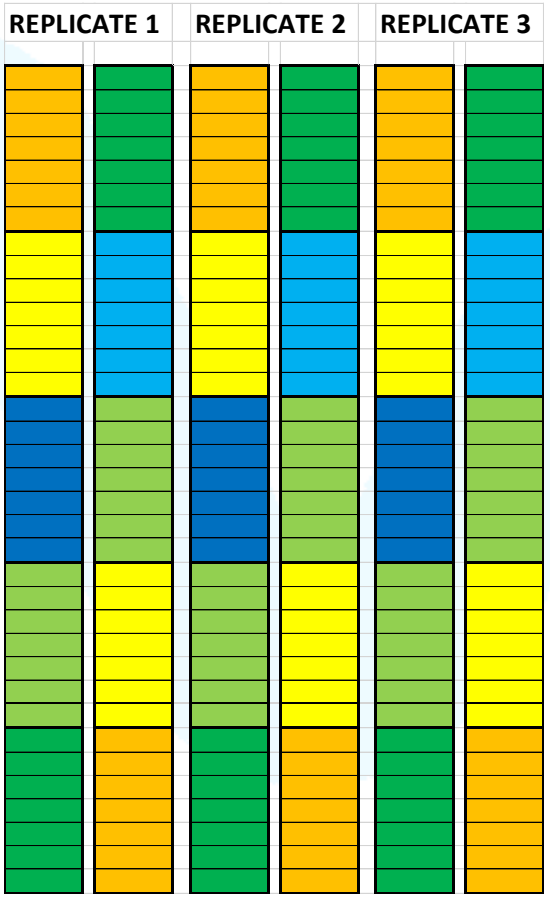
- Alpha-lattice designs
- Individual plots – approx. 9.5m x 2m
- Plots border on long side

- **Flexibility** for each trial operator
- **Assortment of possible layouts**

- e.g. For 3 reps of 210 varieties

3 banks of 70 plots (10 blocks of 7 plots)

6 banks of 35 plots (5 blocks of 7 plots)



Modelling considerations (1)

Spatial trends are a source of **systematic** variation.

Sources of non-variety variation:

Global trends
More localised variation
Extraneous variation (Management practices etc.)

Variability between rows:

"Row" as factor.

"row" as variate. Linear trend across the rows

Modelling considerations (2)

Spatially correlated errors? – very localised patterns

Potentially in two dimensions.

Separability: $r(u,v) = r(u,0) * r(0,v)$

Commonly assumed. Some biological basis.

Simplifies matters. Rarely tested!

Separable Rows x Columns correlated error structures

ID x ID (uncorrelated) AR(1) x AR (1)

AR1 x ID ID x AR1

Modelling considerations (3)

Inclusion of a “nugget”?

Possible to fit measurement error / “units” / nugget term which is additional to spatial error modelling.

Nugget variance is the value of the variogram at a distance of 0.
Nugget arises when the spatial separation $\longrightarrow$ 0 but variogram >0.

Can arise with small range spatial processes which have ranges smaller than the sampling distance. Also measurement error.

Candidate models – within trial

Fitted to **each** trial **separately**:

Baseline - Standard incomplete block analysis

10 candidate spatial models (of varying complexities) incorporating combinations of:

Fixed: Variety + row + column

Random: Rep/Block + units + Row + Column + spl(row) + spl(column)

Residual: either ID x ID or AR1 x AR1 or ID x AR1

Model fit comparisons (1)

Comparison of models differing in fixed effects

Problematic with REML-based AIC and BIC

Residual likelihoods are not comparable

Verbyla (2019): Full likelihood can be decomposed into two parts:

- Marginal likelihood (residual likelihood)
- Conditional likelihood (fixed effects estimation based on this)

Model fit comparisons (2)

Comparison of models differing in fixed effects

Evaluate FULL likelihood at REML estimates

Use full-likelihood based AIC or BIC for model comparisons

Consequently

Information criteria account for both:

- Fixed effects parameters
- Variance parameters

Over-trials analysis in UK

A two-stage process:

Stage 1: Analysis of **each** trial **separately**

Stage 2: Analysis of **varieties x trials means** from stage 1

Precision from stage 1 not carried forward into stage 2 at present.

Estimates of precision for varietal differences can be obtained both:

1. Within each trial
2. From over-trials analysis.

Improvement in precision within trials does NOT guarantee an improvement in over-trials precision.

Over-trials evaluation of spatial models

Three over-trials analyses using corresponding varieties x trials means.

1. Current UK approach – incomplete block analysis
2. “Best” model from each trial
3. “Best” model overall

Compare variety means and estimates of precision for variety differences.

Consider each National List series (year) separately.

Available data

National List Winter barley trials:

Treated & Untreated from three successive years: 2018 – 2020

National List (NL)

- 2 years of testing for Value for Cultivation and Use
- Trials across the UK
- Successful candidates go onto the National List (marketable)

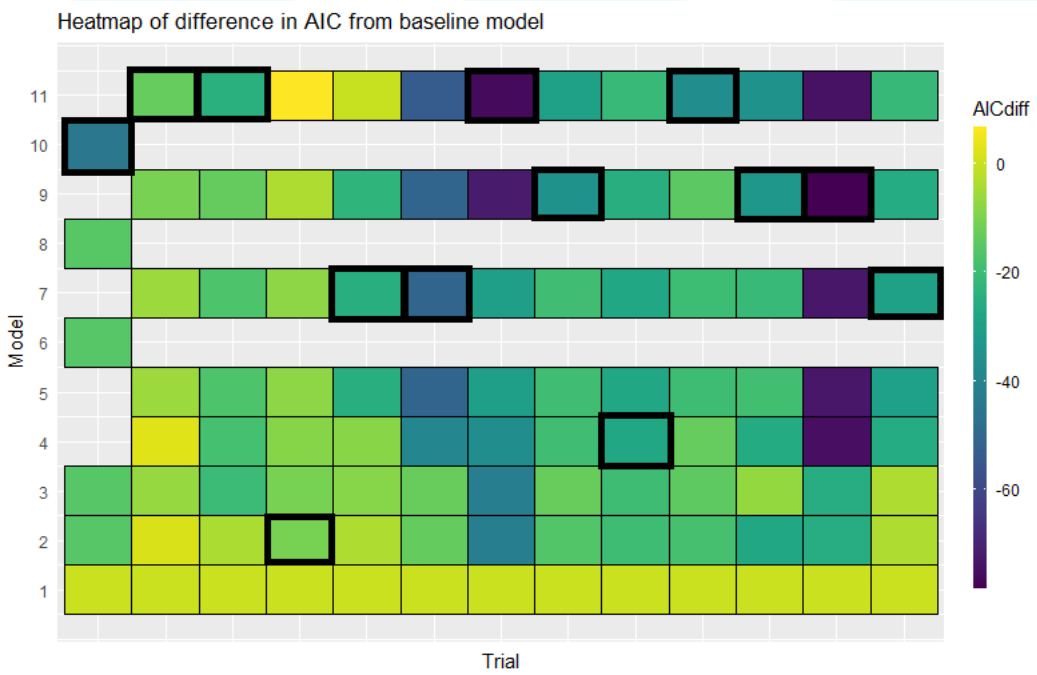
Example data: Winter barley – 2018 (Treated)

Year	Trial	T/U	Plot array	Regular?
2018	A	T	75 x 3	Y
2018	B	T	25 x 9	Y
2018	C	T	25 x 9	Y
2018	D	T	20 x 8	N
2018	E	T	40 x 6	N
2018	F	T	30 x 8	N
2018	G	T	40 x 6	N
2018	H	T	20 x 8	N
2018	I	T	40 x 6	N

Results

Winter Barley 2018 trials

AIC shows spatial models are an improvement on the standard model in all trials, although some only marginally



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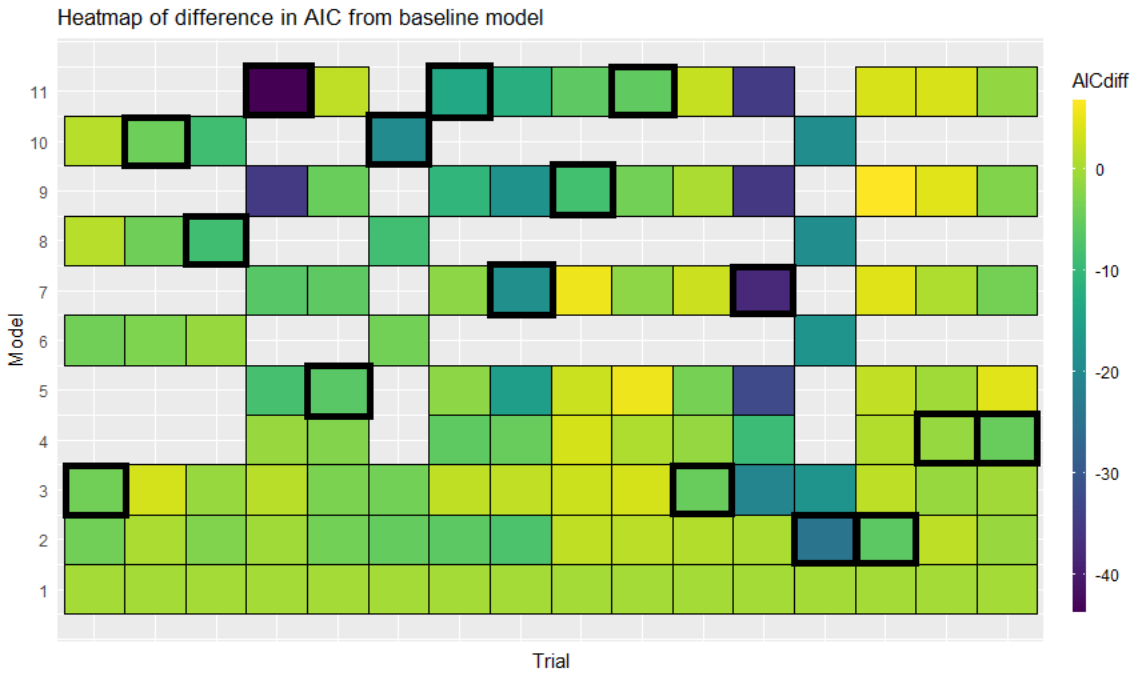

Results

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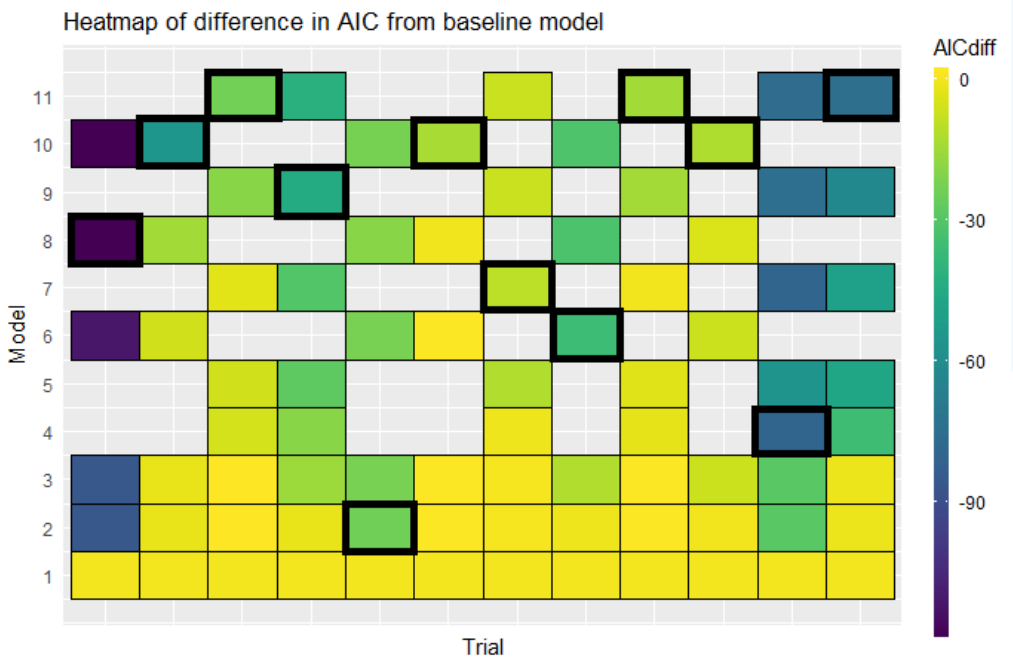


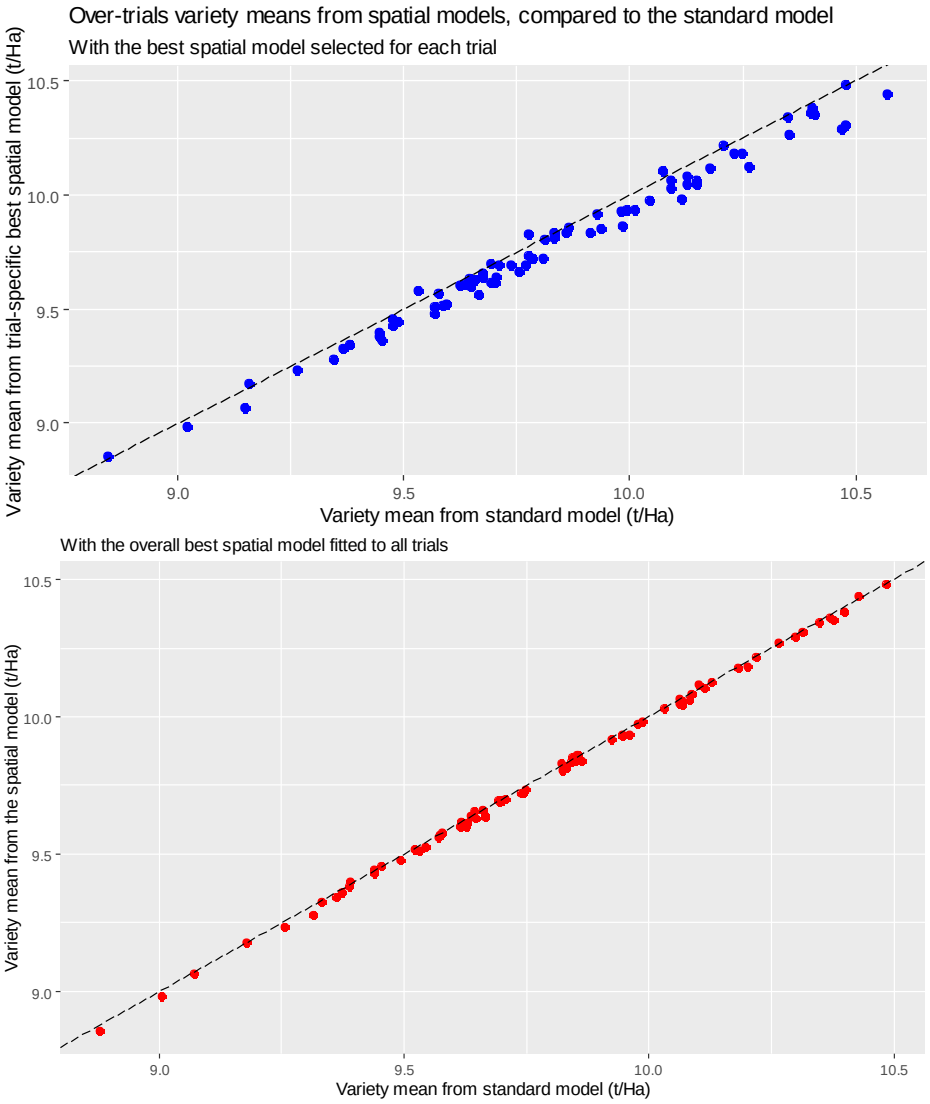
Results: over-trials

Winter Barley 2018 trials

Predicted means are very close to the standard model for the overall best model, slightly more variable for the trial-specific best models

SEDs are slightly smaller for the spatial models

SED (t/Ha)	Standard	Trial specific best spatial model	Overall best spatial model
Mean	0.2204	0.2141	0.2151
Min	0.2084	0.2024	0.2034
Max	0.2657	0.2580	0.2593



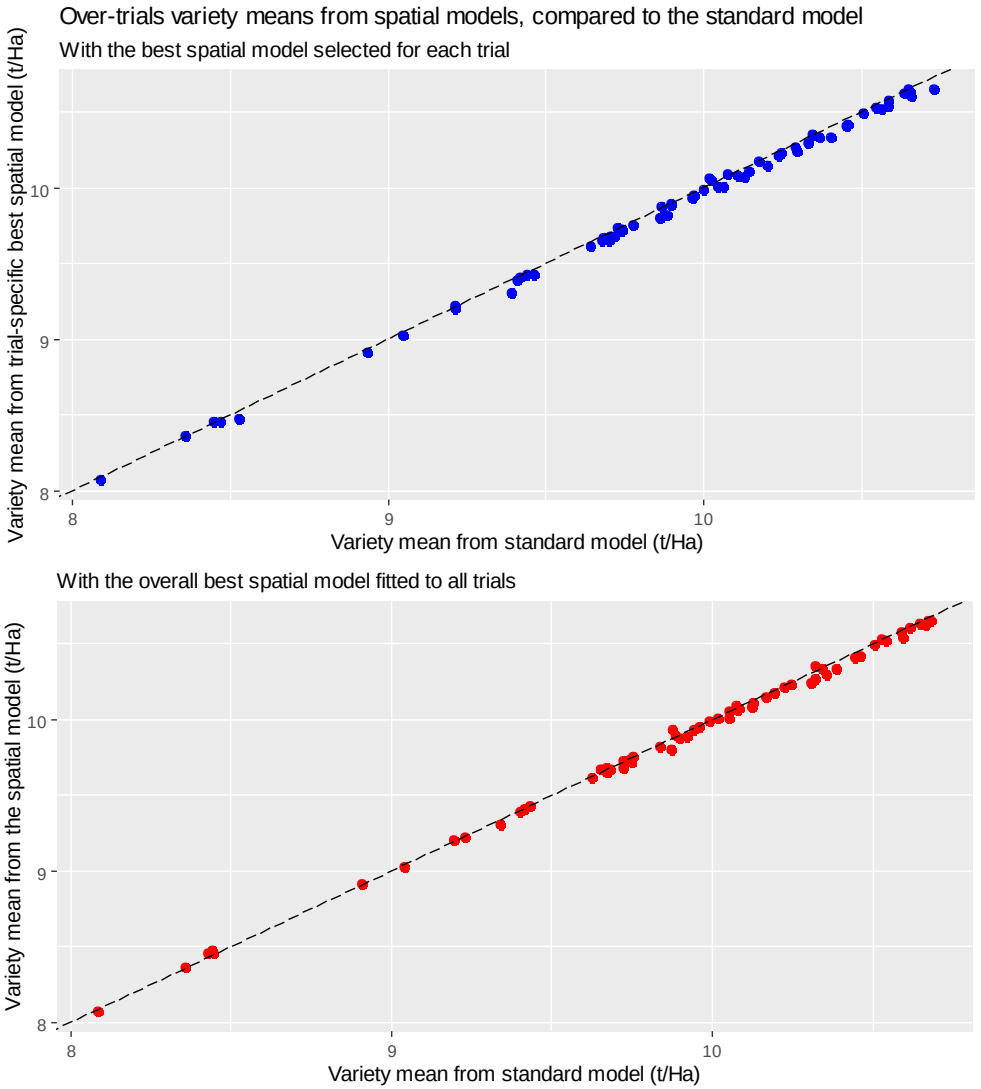
Results: over-trials

Winter Barley 2019 trials

Predicted means are very close to the standard model in both cases

SEDs are slightly larger for the spatial models

SED (t/Ha)	Standard	Trial specific best spatial model	Overall best spatial model
Mean	0.2129	0.2130	0.2135
Min	0.2112	0.2114	0.2118
Max	0.2439	0.2441	0.2445



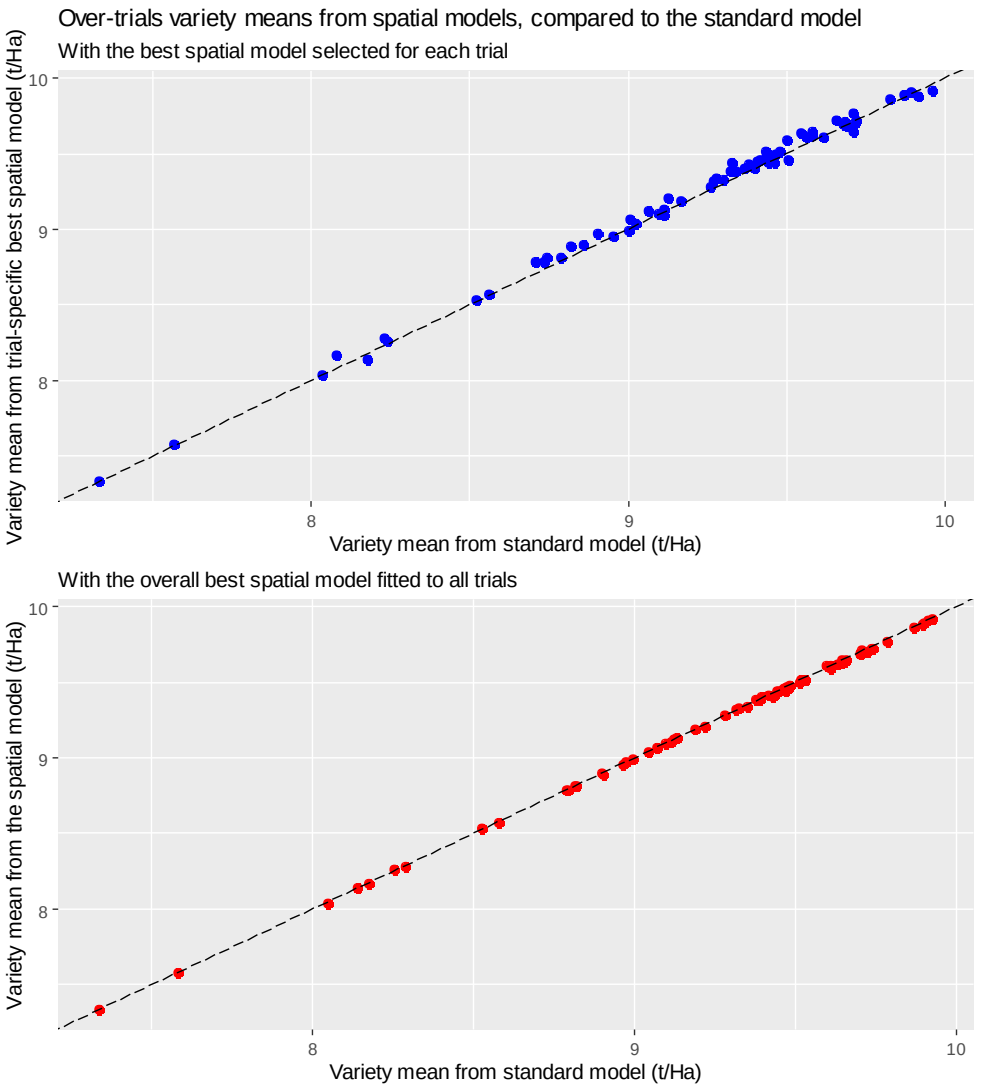
Results: over-trials

Winter Barley 2020 trials

Predicted means are very close to the standard model in both cases

SEDs are slightly smaller for the spatial models

SED (t/Ha)	Standard	Trial specific best spatial model	Overall best spatial model
Mean	0.1684	0.1624	0.1621
Min	0.1672	0.1612	0.1609
Max	0.2033	0.1960	0.1957



Results

Variety rankings are largely unchanged under spatial model.

Over-trials estimates of precision don't improve substantially with spatial model.

Risks of overfitting – Does AIC criteria work in this context?

Practical considerations

Transparency of model selection process critical.

Trial-specific models have drawbacks:

model selection criteria?

Intensive statistical input on each trial?

Operating within a regulatory framework for National List

<u>For post-registration testing (Recommended List)</u>

Margin between recommendation and not can be very small.

Maintaining confidence of the breeders in decision making

but the Australians seem to have negotiated these issues.

Conclusions

We do see underlying spatial trends in our trials - to varying extents in different trials.

Our attempts to model these trends show improvement in (AIC) fit over our current model.

We haven't found substantial improvements in precision with spatial models.

We need to consider the possibility that we are overfitting.

Further Work

Next steps:

- Repeat work on other crops.
- More work needed exploring models using variograms etc. on available trials sets.
- Australians started with AR(1) x AR(1).
  Can we start with AR1(row) x ID(col)?

Open to suggestions!

References

Patterson H.D. and Williams E.R. (1976). A new class of resolvable incomplete block designs. Biometrika, 63, 83-92.

Patterson H.D., Williams E.R. and Hunter E.A. (1978). Block designs for variety trials. Journal of Agricultural Science. 90, 395-400.

Gilmour A.R., Cullis B. R., Verbyla A.P. (1997). Accounting for natural and extraneous variation in the analysis of field experiments. Journal of Agricultural and Environmental Statistics, 2(3), 269-293.

Verbyla A. P. (2019). A note on model selection using information criteria for general linear models estimated using REML. Australian and New Zealand Journal of Statistics, 61(1), 39-50.

Winter barley – 2018 (Untreated)

Year	Trial	T/U	Plot array	Regular?	CV%
2018	SA 121	U	12 x 4	No	Complete block design - single rep trial
2018	SA221	U	10 x 7	Yes	1.2
2018	SA 235	U	10 x 7	Yes	3.3
2018	SA 311	U	20 x 8	No	4
2018	SY 316	U	40 x 4	No	3.3

Winter barley – 2019 (Treated)

Year	Trial	T/U	Plot array	Regular?	CV%
2019	AG 322	T	65 x 2	Yes	4.8%
2019	NS 333	T	26 x 5	Yes	4.7%
2019	ES 332	T	62 x 2	Yes	3.8%
2019	SY 316	T	40 x 5	No	4.5%
2019	KW 309	T	22 x 9	No	3.9%
2019	SU 306	T	35 x 6	No	3.8%
2019	SA 311	T	30 x 7	No	2.9%
2019	HE 352	T	35 x 6	No	2.7%
2019	SS 348	T	33 x 6	No	2.6%
2019	FA 353	T	35 x 6	No	2.2%

Winter barley – 2019 (Untreated)

Year	Trial	T/U	Plot array	Regular?	CV%
2019	ES 332	U	62 x 2	Yes	6.3% REJECTED
2019	NS 333	U	26 x 5	Yes	5.7%
2019	SY 316	U	26 x 5	Yes	4.0%
2019	SA 311	U	20 x 7	No	5.6%
2019	HE 352	U	35 x 4	No	3.9%
2019	SS 348	U	33 x 4	No	3.5%

Winter barley – 2020 (Treated)

Year	Trial	T/U	Plot array	Regular?	CV%
2020	AG 332	T	70 x 3	Yes	4.9%
2020	ES 332	T	69 x 2	Yes	4.5%
2020	NS 333	T	70 x 2	Yes	4.4%
2020	SY 316	T	35 x 6	Yes	4.2%
2020	SA 311	T	35 x 6	Yes	3.0%
2020	SS 348	T	35 x 6	Yes	2.0%
2020	FA 353	T	35 x 6	Yes	1.8%
2020	SU 306	T	36 x 6	Yes but …	5.2%
2020	KW 309	T	28 x 9	No	2.6%

Winter barley – 2020 (Untreated)

Year	Trial	T/U	Plot array	Regular?	CV%
2020	SA 311	U	35 x 4	Yes	3.3
2020	SY 316	U	35 x 4	Yes	2.8
2020	SS 348	U	35 x 4	Yes	3.8
2020	ES 332	U	69 x 2	Yes	3.8
2020	NS 333	U	70 x 2	Yes	4.5

Results

1. Fixed: Variety, Random: Rep + Rep:Block, Error structure: ID x ID (baseline incomplete block model)
2. Fixed: Variety, Random: Rep + Rep:Block, Error structure: AR(Row) II
3. Fixed: Variety, Random: Rep + Rep:Block, Error structure: AR x AR ***
4. Fixed: Variety, Random: Rep + Rep:Block + units, Error structure: AR(Row) II
5. Fixed: Variety, Random: Rep + Rep:Block + units, Error structure: AR x AR *** II
6. Fixed: Variety, Random: Rep + Rep:Block + units + Row, Error structure: AR(Row)
7. Fixed: Variety, Random: Rep + Rep:Block + units + Row + Column, Error structure: AR x AR *** II
8. Fixed: Variety + row, Random: Rep + Rep:Block + units + Row, Error structure: AR(Row) I
9. Fixed: Variety + row + column, Random: Rep + Rep:Block + units + Row + Column, Error structure: AR x AR *** I
10. Fixed: Variety + row, Random: Rep + Rep:Block + units + Row + spl(row), Error structure: AR(Row) II
11. Fixed: Variety + row + column, Random: Rep + Rep:Block + units + Row + spl(row) + spl(column), Error structure: AR x AR *** III