



ROTHAMSTED
RESEARCH



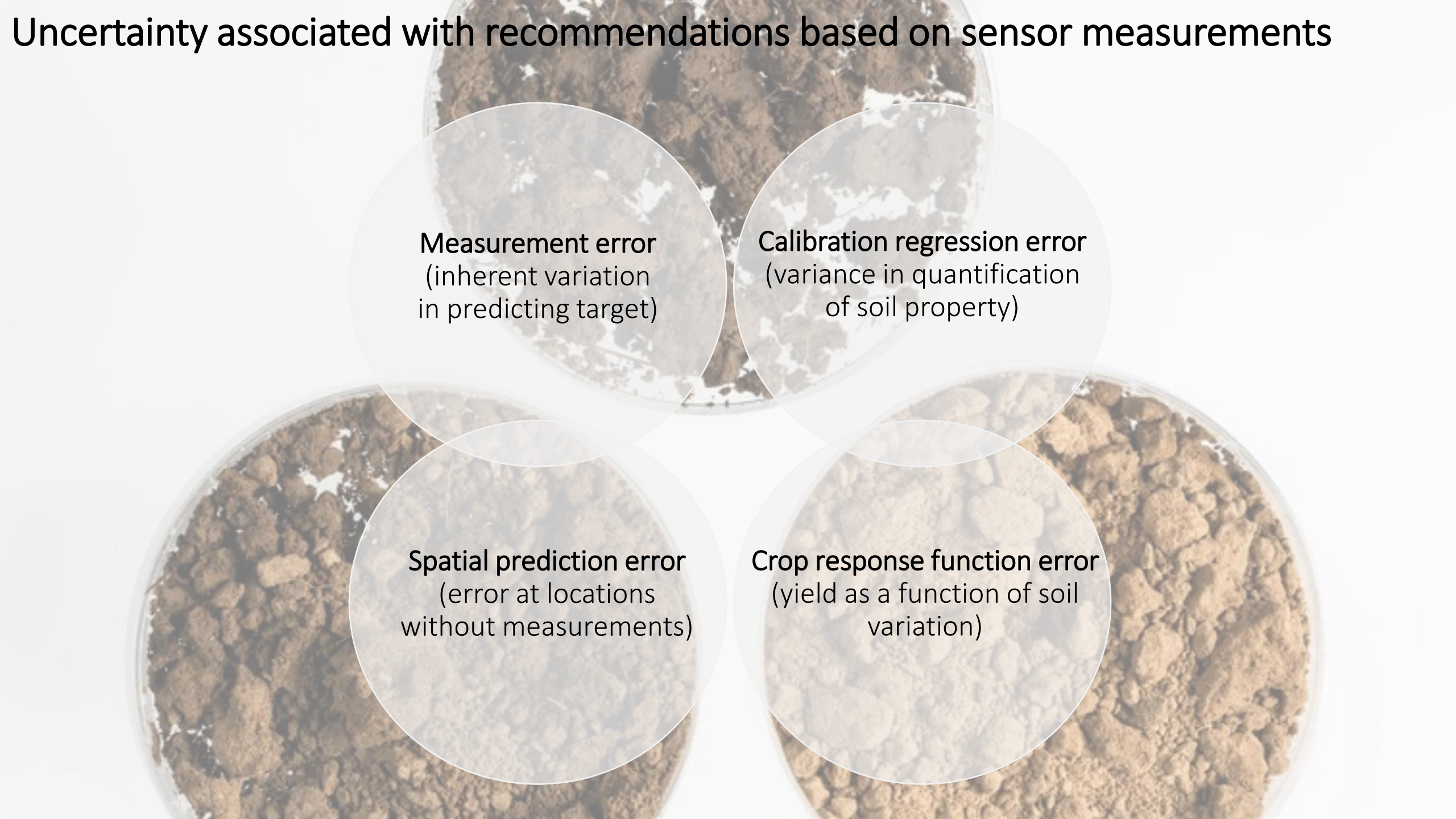
A loss function approach to soil sensing

TS Breure^{1,2} · AE Milne¹ · JA Hannam² · SM Haefele¹ · JM Prout^{1,2} · R Webster¹ · R Corstanje²

¹ Rothamsted Research, Harpenden, UK

² Cranfield University, Cranfield, UK

Uncertainty associated with recommendations based on sensor measurements



Measurement error
(inherent variation
in predicting target)

Calibration regression error
(variance in quantification
of soil property)

Spatial prediction error
(error at locations
without measurements)

Crop response function error
(yield as a function of soil
variation)

Objective:

Evaluate the effect of
uncertainty from
NIR/MIR/XRF
predicted soil
properties
on decision-making

We predicted the available
P and K content from
NIR/MIR/XRF spectroscopy
data and applied universal
kriging for 4 fields in the
UK.

The expected loss is
computed for variable-rate
and uniform application of
fertilizer given the
uncertainty in the kriging
predictions

Case-study area



Source: UK Environment Agency

LiDAR data of the
Cambridgeshire fens



Soil profile within the
Cambridgeshire fens

Peat

Alluvial
silt

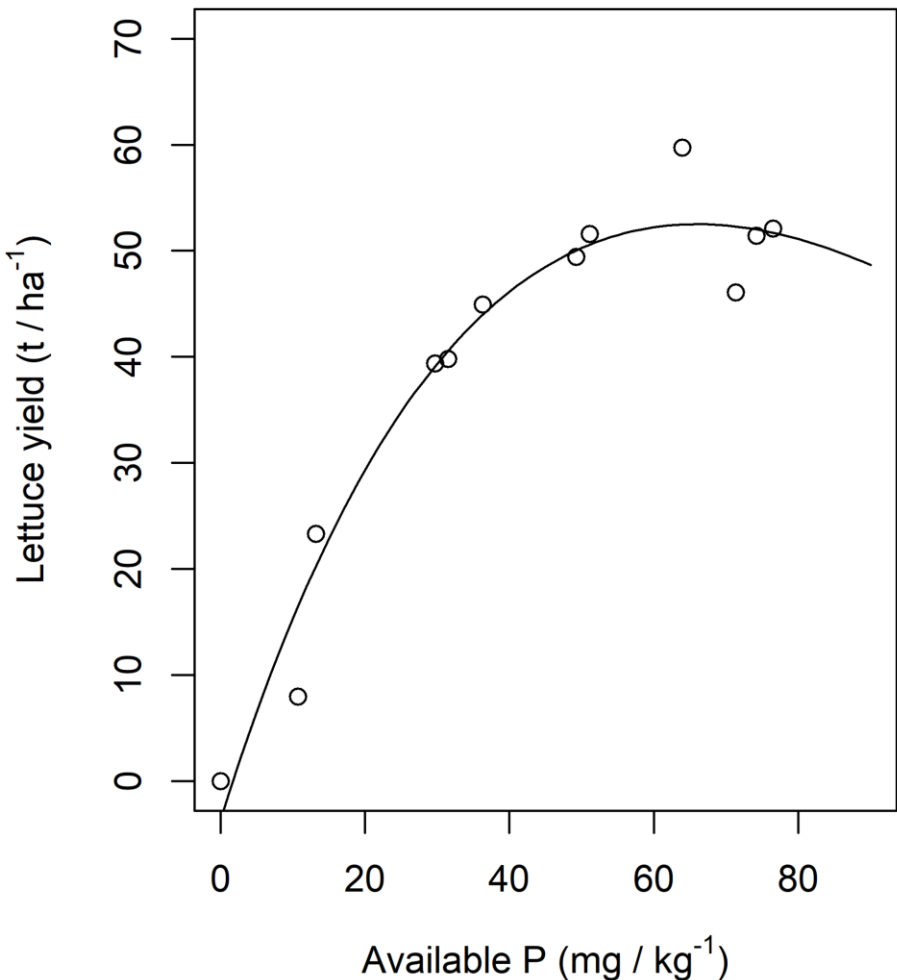
Marine
silt



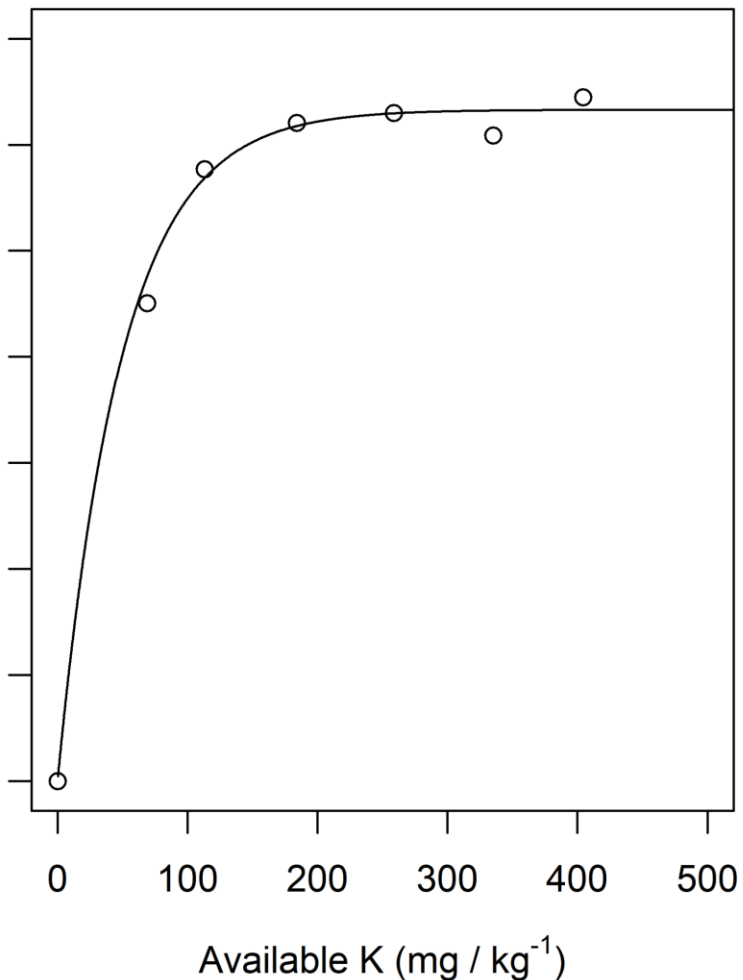
United Kingdom

Methods (1) : Dose response curves to inform fertilizer application

$$Profit(F) = M \times Yield - V \times F ,$$



(Prasad et al. 1988)

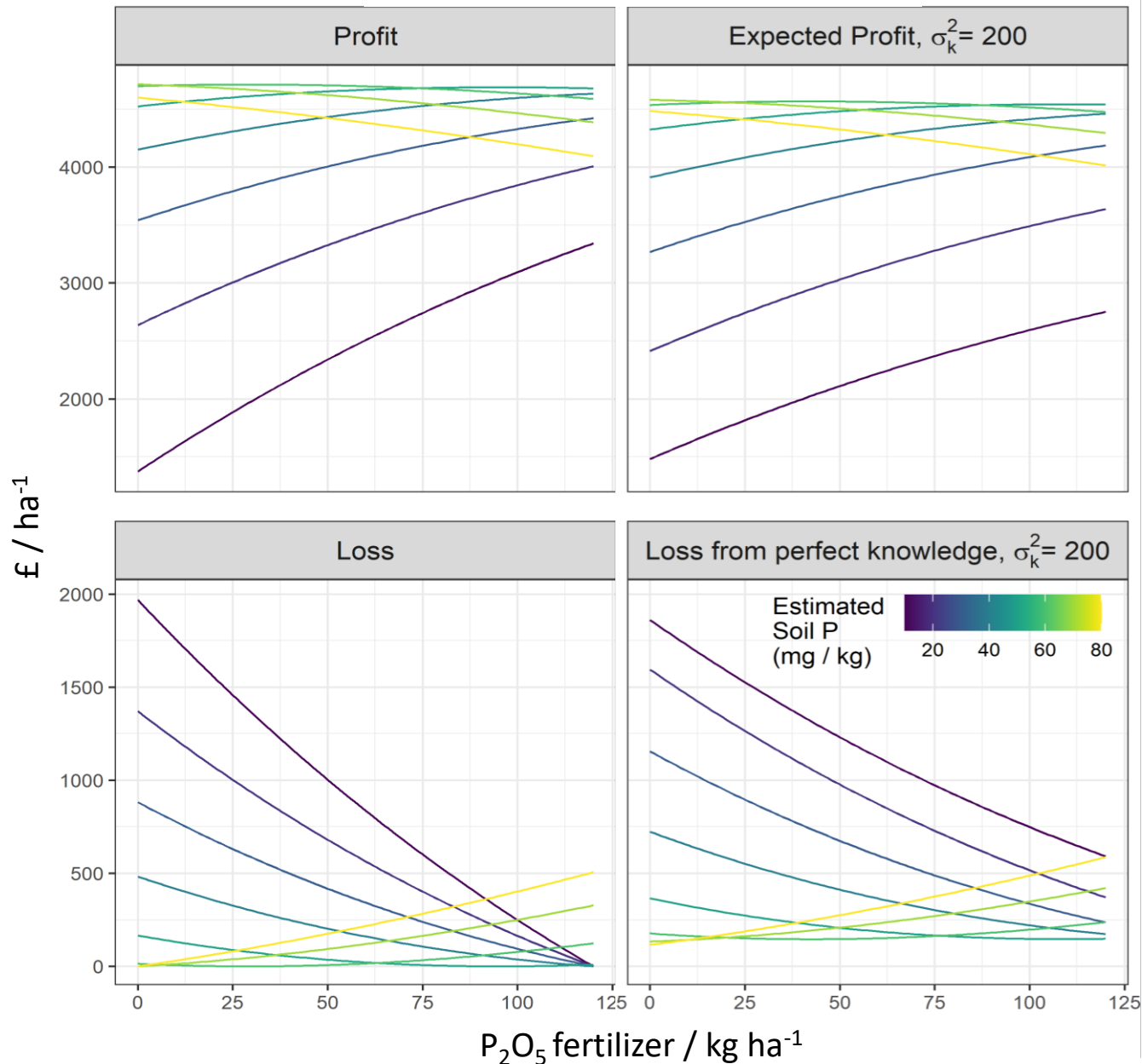


(Greenwood et al. 1980)

Where;
M = price of the crop
V = price of fertiliser
F = fertiliser applied (kg / ha⁻¹)

Methods (2) : Loss function illustration

$$L(F) = Profit(F_0) - Profit(F) ,$$



The loss is the difference in Profit from fertiliser applied with perfect information (F_0) subtracted with the Profit under fertiliser regime F

The loss increases under uncertainty (right column) irrespective of the estimate soil nutrient value at that location

Where the perfect information (i.e. the 'true' values) are assumed to be the kriging predictions

Methods (3) : Contrast variable rate- with uniform fertiliser application

Given the uncertainty at each kriged location, we compute the expected loss by:

$$E[L(F)] = Profit(F_0, S) - \int_0^\infty \{Profit(F, s)\} f(s) ds .$$

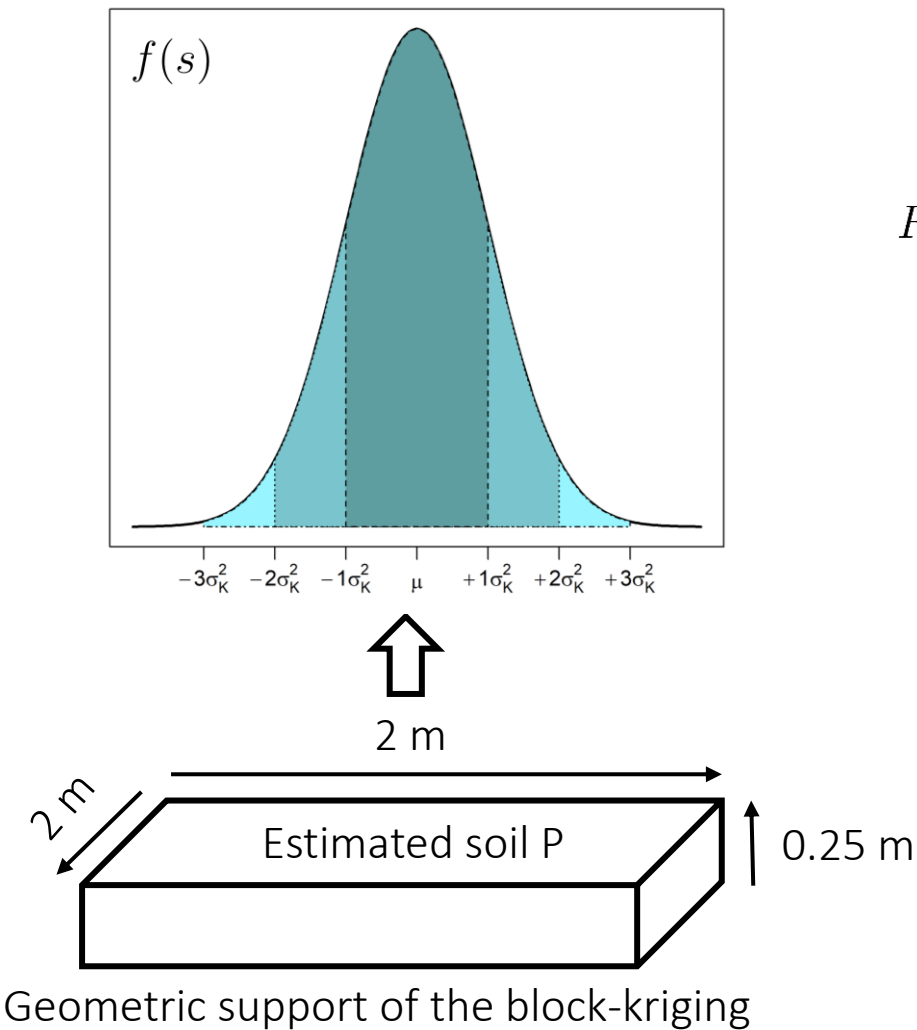
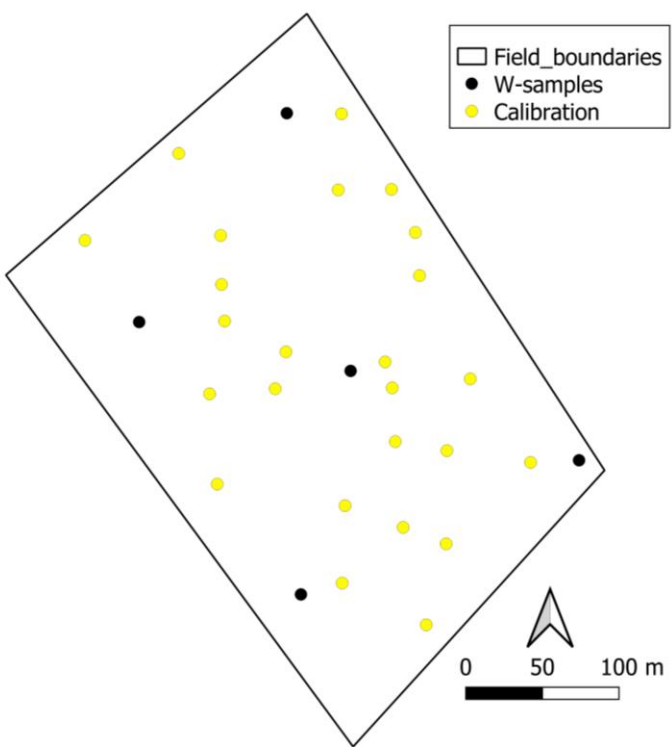
Where F takes the value of;

F_{opt} = Optimum fertilizer that minimizes the expected loss under uncertainty

or;

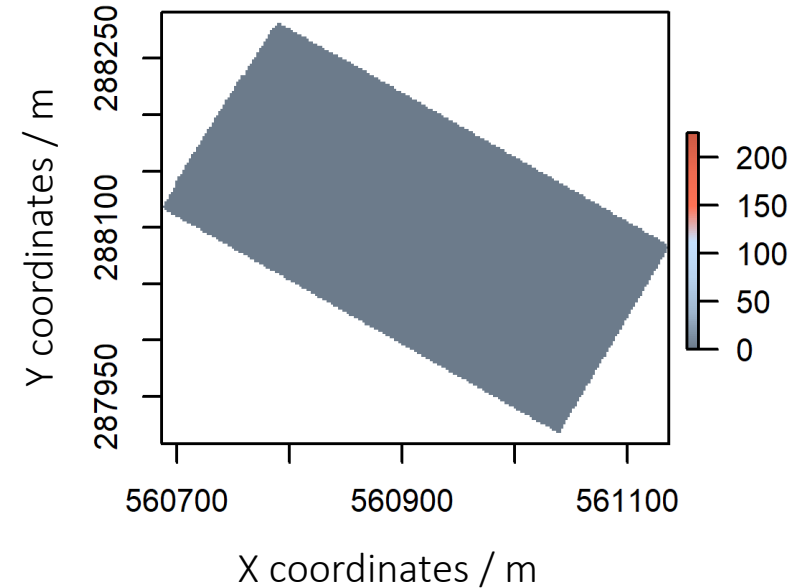
F_{UA} = Fertilizer under uniform application based on field-average from W-design

Where the Profit for fertiliser regime F is calculated given the error distribution $f(s)$, denoted by the kriging variance at each location;

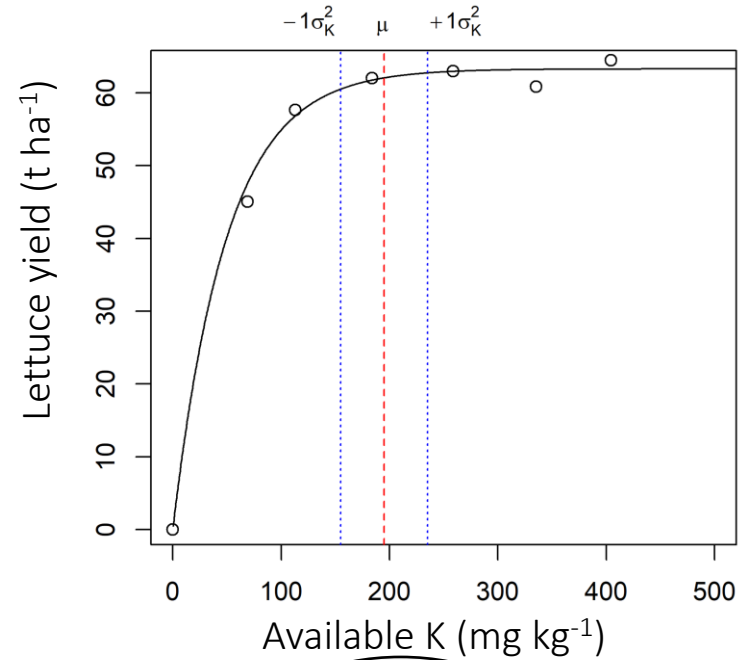


Results (1) : Observed implications of loss function approach

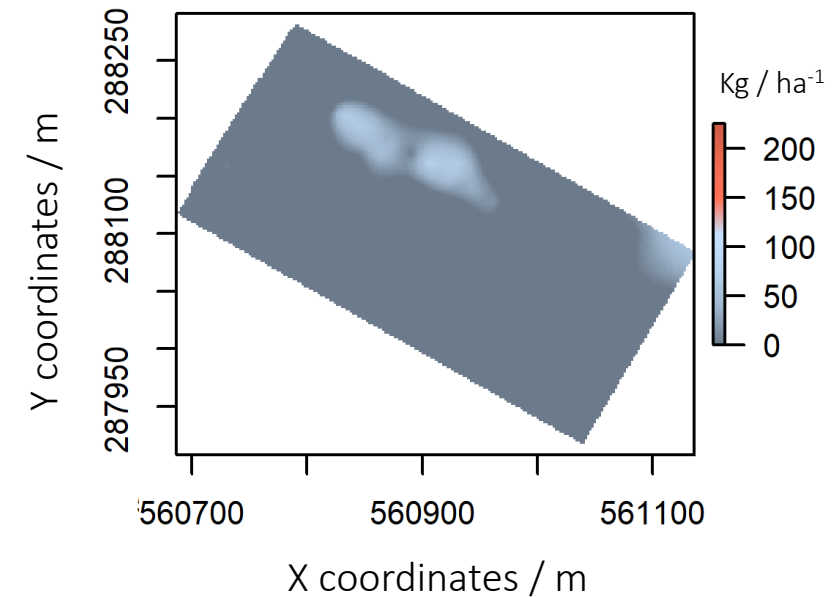
F_0 for K_2O fertilizer



DRC for K_2O fertilizer



F_{opt} for K_2O fertilizer



For this example; we would not apply any fertilizer under perfect information (F_0) as predicted K values sit on the asymptote of the DRC



However, uncertainty increased the probability of predicted K falling below asymptote



Risk averse application of fertilizer under uncertainty (F_{opt}) was more economical due to asymmetry of the loss function

Results (2): Evaluating variable rate versus uniform application

Field	Area / ha ⁻¹	Nutrient	Fertilizer / kg ha ⁻¹		Expected loss / £ ha ⁻¹	
			F_{opt}	F_{UA}	$E[L(F_{\text{opt}})]$	$E[L(F_{\text{UA}})]$
1	8.2	P	107	120	33	45
2	16.9		95	120	30	54
3	5.1		98	62	34	110
4	8.9		61	57	90	137
1	8.2	K	3	0	9	9
2	16.9		44	0	21	36
3	5.1		221	144	44	117
4	8.9		17	0	8	11

P₂O₅ fertiliser use is lower under variable rate application(F_{opt}) compared to uniform application (F_{UA}) for two fields

Expected loss is lower for variable rate application compared to uniform application

Concluding remarks

1. Uncertainty resulted in a risk-averse application of fertilizer to minimize the expected loss

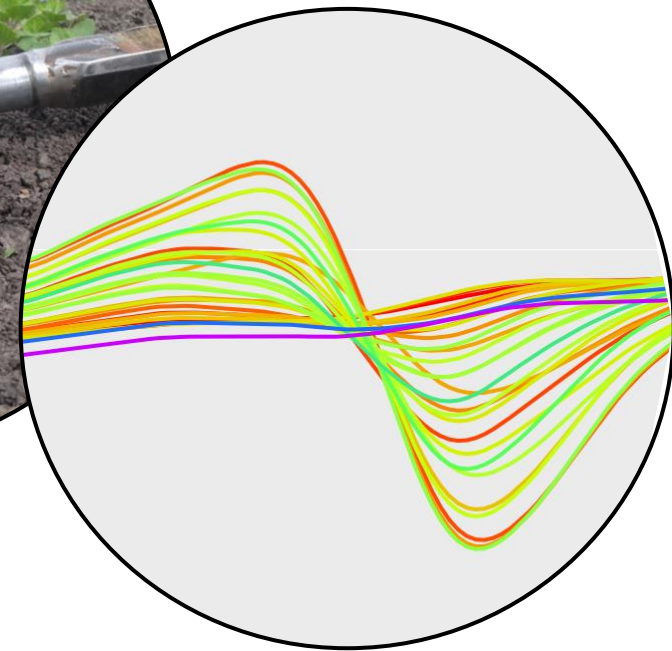
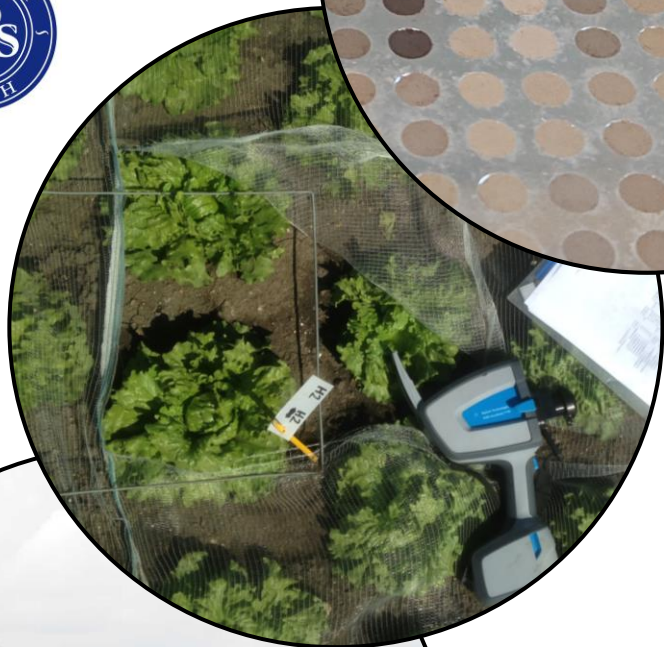
2. Expected loss was further affected by the range of predicted P and K values relative to the parameterisation of the dose-response curve

3. There were economic and environmental incentives for variable rate fertiliser compared to uniform application

4. The difference in expected loss between F_{opt} and F_{UA} gives an indication for cost-effective implementation of spectroscopy to inform variable rate fertilizer



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DSPACE

<https://dspace.org/>

Agricultural decision-making under uncertainty: a loss function on the kriging variance from soil properties predicted by infrared and X-ray fluorescence spectroscopy

Breure, Timo S.; Haefele, Stephan M.; Webster, Richard; Hannam, Jacqueline A.; Corstanje, Ronald ...

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EGU: European Geophysical Union

<https://doi.org/10.5194/egusphere-egu21-12615>

Breure T, Haefele SM, Webster R, et al., (2021) Agricultural decision-making under uncertainty: a loss function on the kriging variance from soil properties predicted by infrared and X-ray fluorescence spectroscopy. In: European Geophysical Union General Assembly 2021, 19-30 April 2021, Virtual Event