Is there potential value in more precise broadacre cropping system management ?

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PRECISION AGRICULTURE LABORATORY

Precision agriculture offers the possibility of growing better quality crops, while optimising the use of inputs and minimising environmental impacts. It is a revolution in agriculture brought about by the application of information technology.

The Precision Agriculture Laboratory (PA Lab) was established at the beginning of 2012 to operate within the University of Sydney's Centre for Carbon, Water and Food. The PA Lab is the descendant of the Australian Centre for Precision Agriculture (ACPA) which was established in 1995.

The mission of the ACPA was to provide excellent PA science and training, leading agricultural industries towards incorporating practical, sustainable precision agricultural management techniques. The ACPA built an outstanding national and international reputation by innovatively prosecuting its mission.

The PA Lab is well placed to continue this challenge in an exciting environment where PA technologies and industry knowledge are maturing within a range of industries, and PA will become a crucial component in sustainably (commercially and environmentally) managing all inputs, natural retentions and emissions across agricultural operations.

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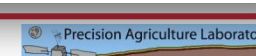
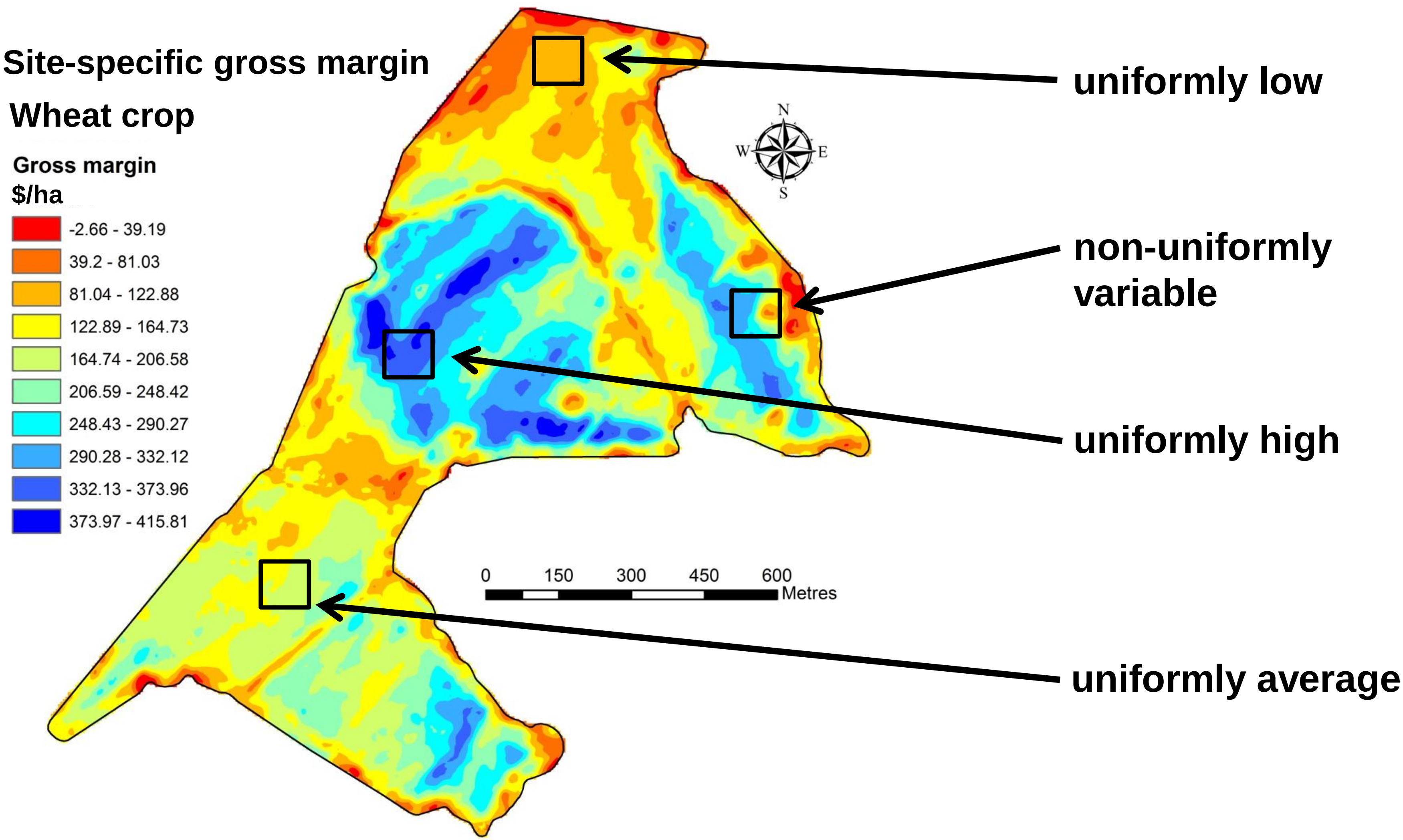


Is there potential value in more precise agricultural management ?

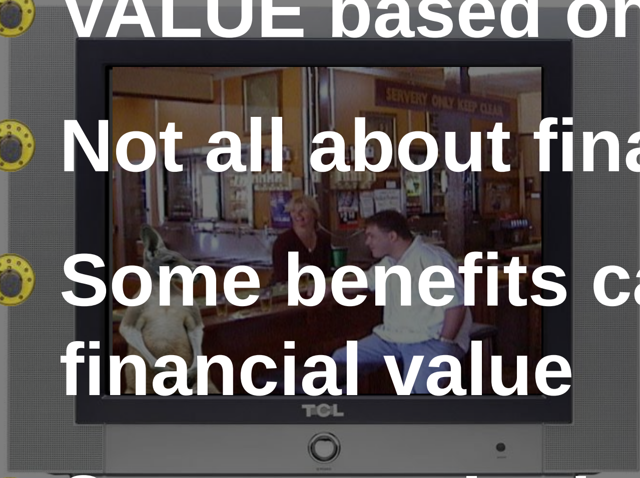
Site-specific gross margin

Wheat crop

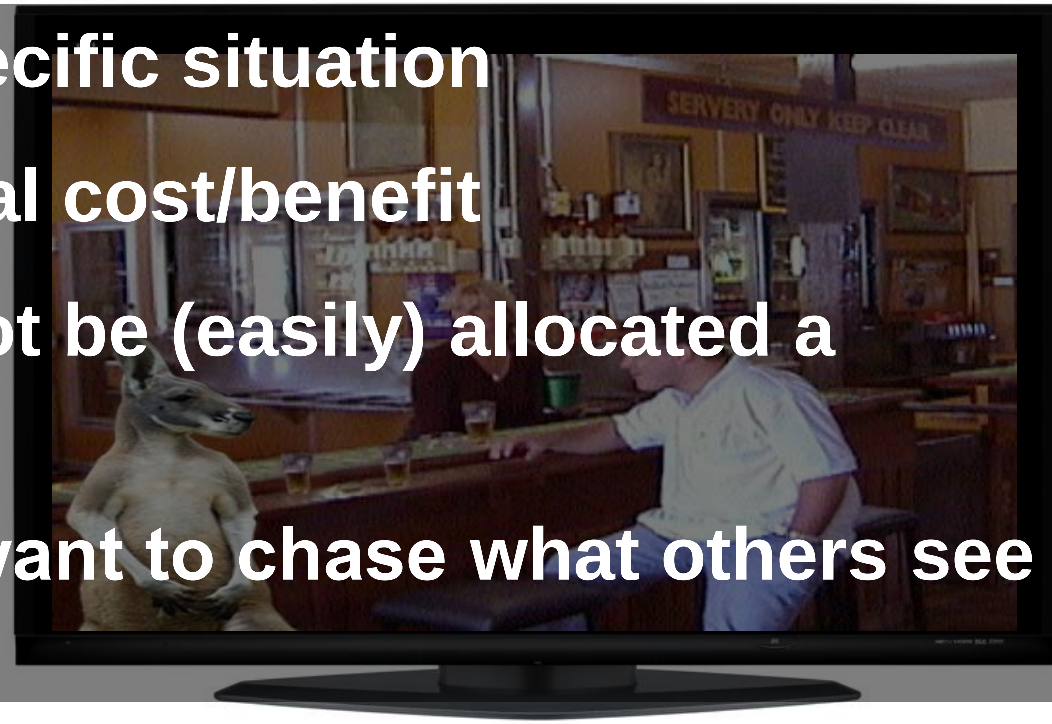


Value

$200



$3000



- **VALUE based on specific situation**
- **Not all about financial cost/benefit**
- **Some benefits cannot be (easily) allocated a financial value**
- **Some people don't want to chase what others see as 'VALUE'**

Precision Agriculture

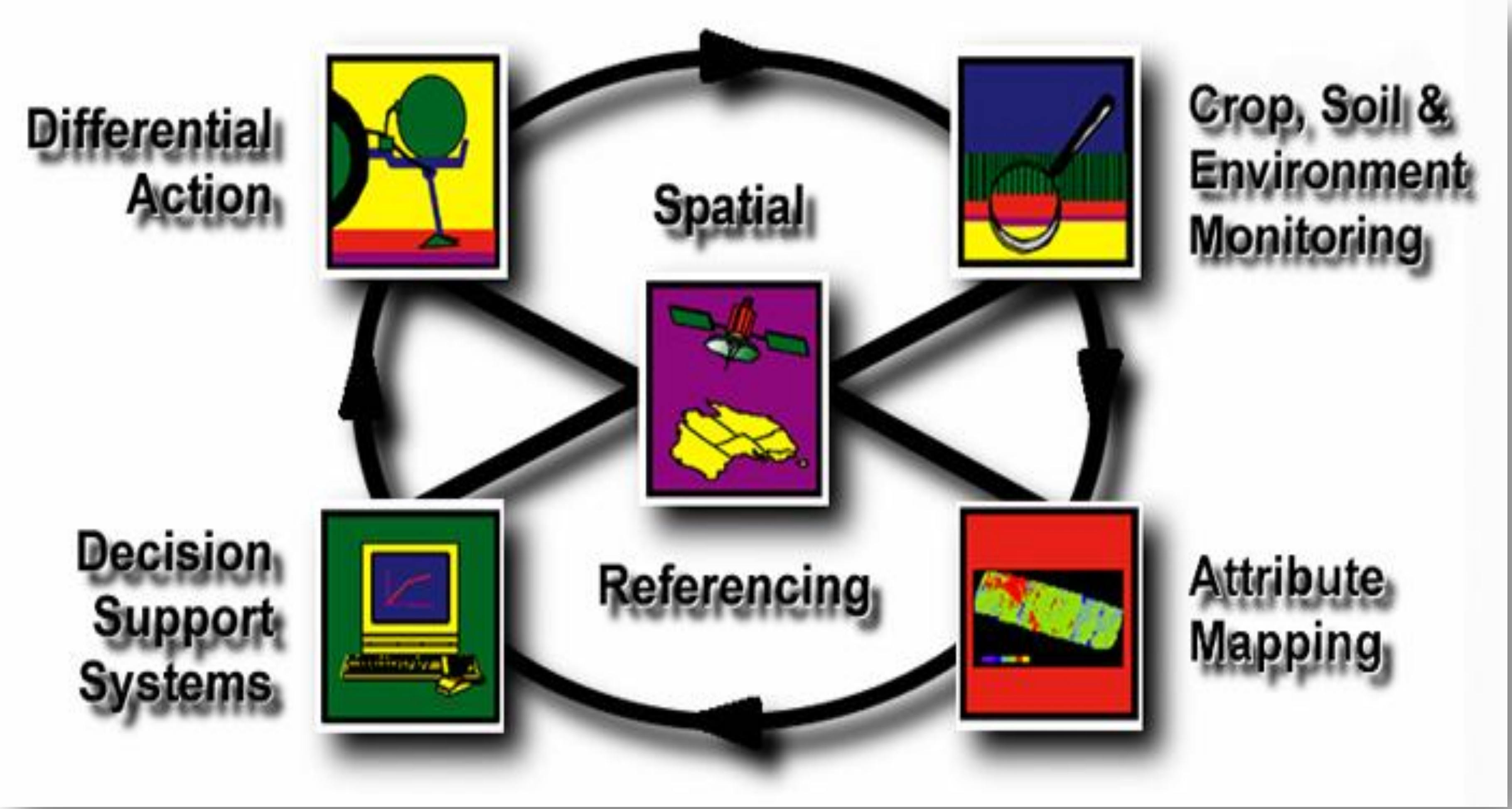
A philosophy aimed at increasing long term, site-specific and whole farm production efficiency, productivity and profitability while minimising unintended impacts on the environment.

Site-Specific Crop Management

SSCM is a form of Precision Agriculture (PA) whereby decisions on resource application and agronomic practices are improved to better match soil and crop requirements as they vary in the field.

- **In practice it creates the opportunity to increase the number of (correct) decisions per hectare made about crop management.**
- **It is a logical step in the evolution of agricultural management systems toward increased efficiency of input use, minimised waste and improved product provenance.**

Site-specific crop management



Fits with the cyclical nature of seasonal crop management

Site-specific crop management

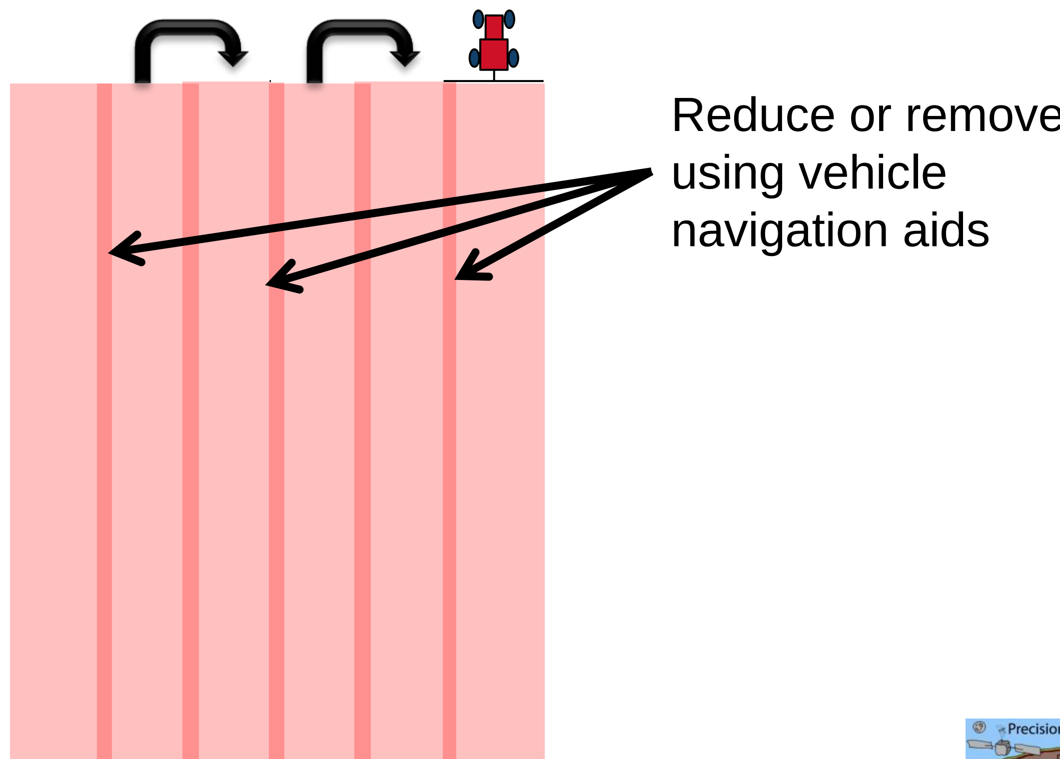
- In a typical cropping enterprise, inputs such as fertiliser, chemicals, seed and labour make up two thirds of the variable costs.
- Using PA to reduce some of these costs is the simplest way to gain a financial and environmental benefit from a precision agriculture investment.
- Using these inputs more efficiently to produce a higher input to yield ratio, increases returns further.
- In reality, the benefits of PA are likely to come from a mix of input savings and improved efficiency.

Vehicle navigation aids

Guidance and autosteer

Application overlap using conventional marking tools can be anywhere from 0.5 metre to 1.0 metres *i.e.*

- 6% to 11% on a 9 metre wide sowing implement; and
- 2% to 4% on a 27 metre wide spraying implement.



Vehicle navigation aids

Vehicle navigation aids

Guidance and autosteer

Reducing overlap down to 10cm *i.e.*

- 1% on a 9 metre wide sowing implement; and
- 0.4% on a 27 metre wide spraying implement.

Produces input savings of between:

- 5% and 10% on a 9 metre wide sowing implement; and
- 1.6% and 3.6% on a 27 metre wide spraying implement.

Using 2012 DPI crop input budget costs for wheat in Nth NSW @ yield goal 3.5 t/ha

Translates to savings of between:

- A$12/ha and A$23/ha on seed, fertiliser and machinery costs at sowing; and
- A$1.40/ha and A$3.20 /ha on herbicide, fungicide and machinery costs at chemical application.

Total savings of between A$13.40/ha & A$26.20/ha + *assoc. environmental benefits*

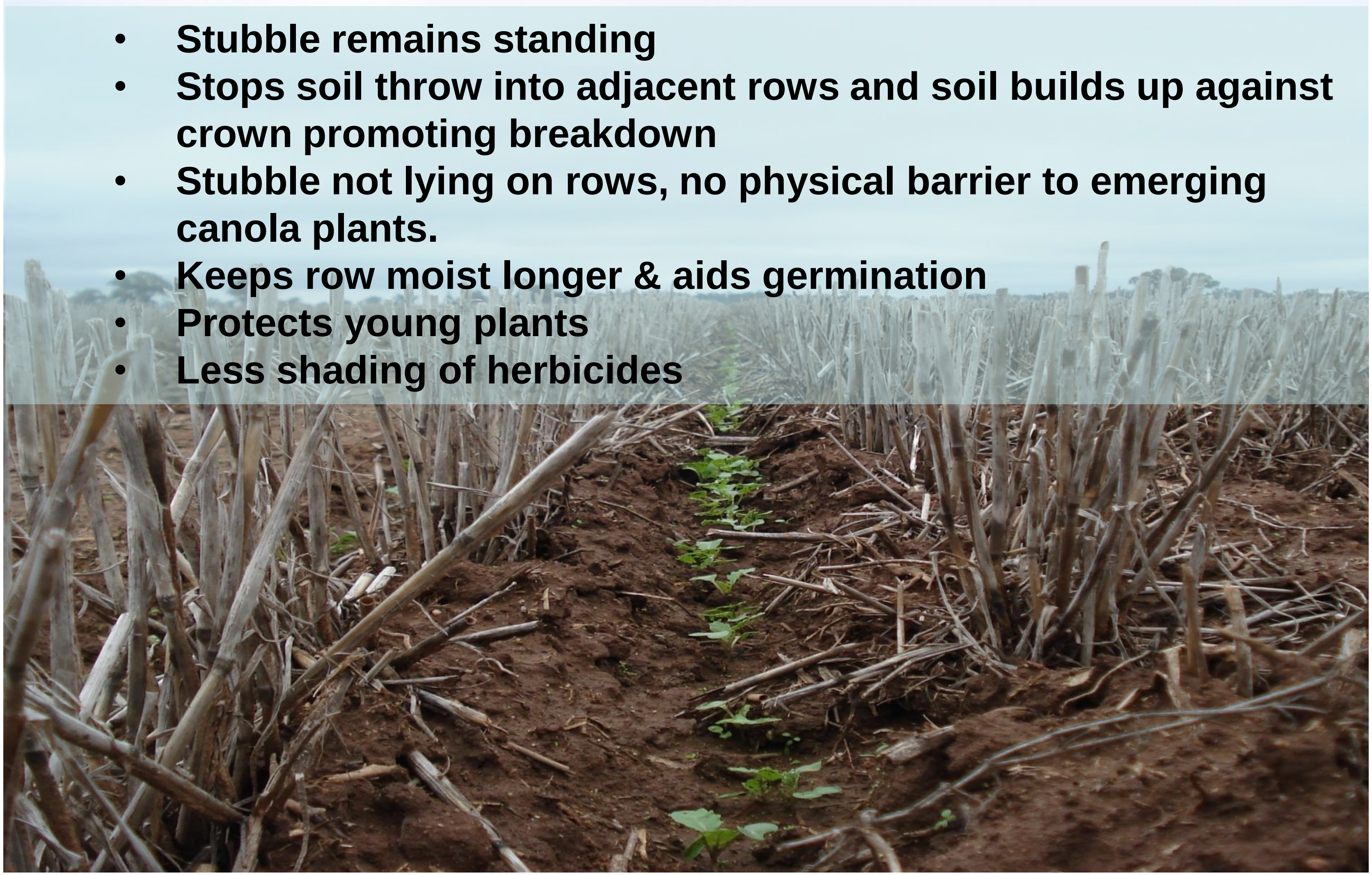
Vehicle navigation aids

- The impact these savings have on the farming gross margin will depend on the proportion that these inputs contribute to variable costs on each farm, but generally the improvement in gross margin means that the cost of any investment in auto-steer/guidance is recouped over a few seasons.

- On top of this there are other agronomic benefits from adopting high-precision autosteer systems. These include:
  - improved soil condition away from wheel tracks;
  - inter-row sowing options; and
  - increased opportunity for operational timeliness.

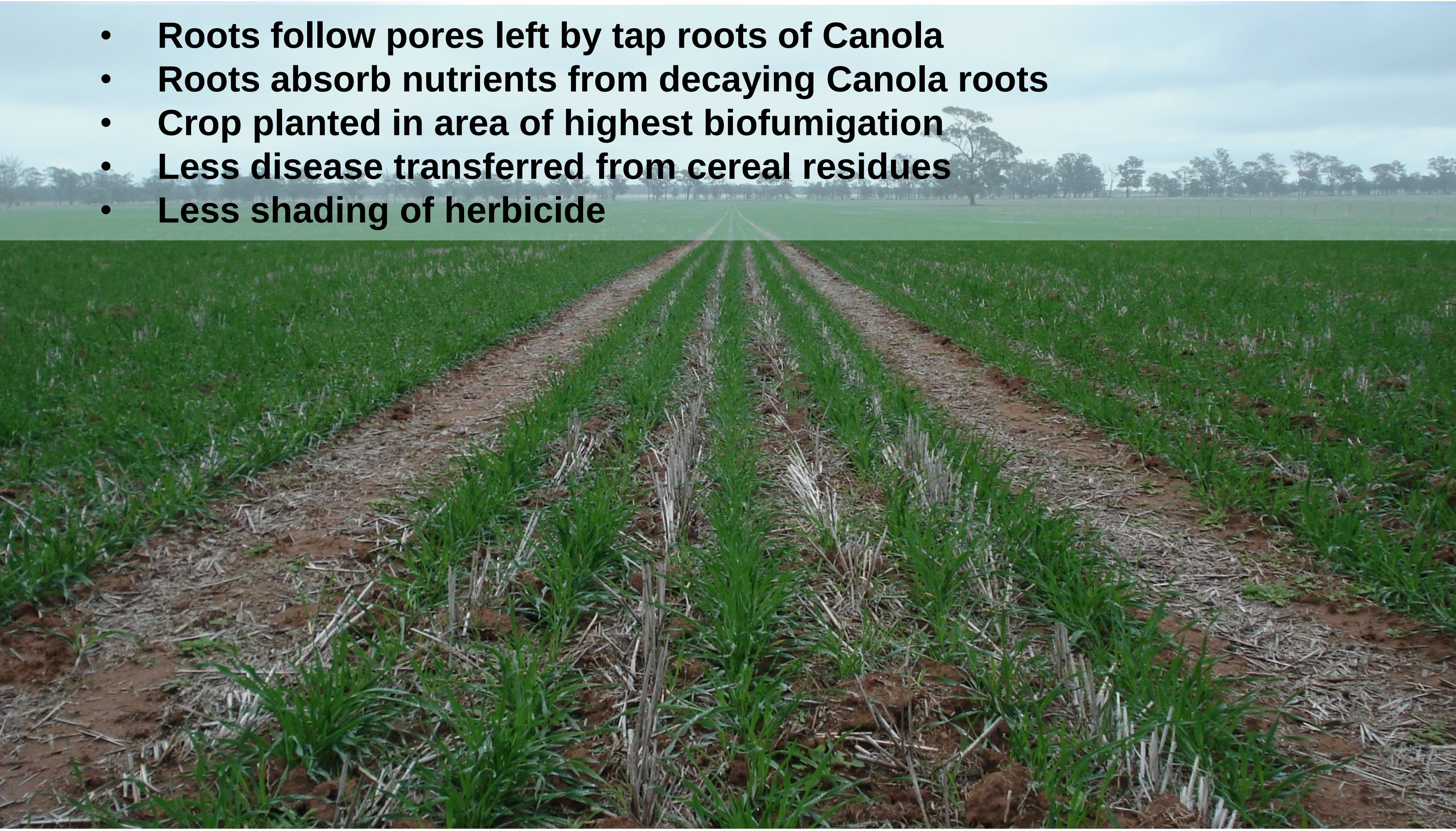
CANOLA - sown between wheat stubble row

- Stubble remains standing
- Stops soil throw into adjacent rows and soil builds up against crown promoting breakdown
- Stubble not lying on rows, no physical barrier to emerging canola plants.
- Keeps row moist longer & aids germination
- Protects young plants
- Less shading of herbicides



CEREAL - Sown *ON* Canola row, *BETWEEN* previous Cereal

- Roots follow pores left by tap roots of Canola
- Roots absorb nutrients from decaying Canola roots
- Crop planted in area of highest biofumigation
- Less disease transferred from cereal residues
- Less shading of herbicide



Variable-rate herbicide

Manufacturer	Rometron Agricultural B.V
Height of operation	1 metre
Field of view	100cm, divided in 5 sections of 20cm
View angle	nadir
Active light source	Red LED
Data output	Detects flourecence from chlorophyl
Calibrations	Green plants on soil or stubble

Variable-rate herbicide

	Field 1	Field 2
Seasons	1	1
Area sprayed	246 hectares	120 hectares
Weeds	Peachvine, milkthistle, volunteer cotton, fleabane	Volunteer cotton
Herbicide	2.6 L/ha Rup + 4 L/ha Surpass	1 L/ha Starane + 1 L/ha MCPA
Area sprayed	11.8 ha (4.5%)	18 ha (15%)
Cost of blanket sprayed herbicide	$7840	$3360
Cost of spot sprayed herbicide	$353	$504
Average saving	$30.43/ha	$23.80/ha
Total saving	**$7487**	**$2856**

Data supplied by David Brownhill Merrilong Pastoral Company, Spring Ridge, NSW.

Variable-rate herbicide

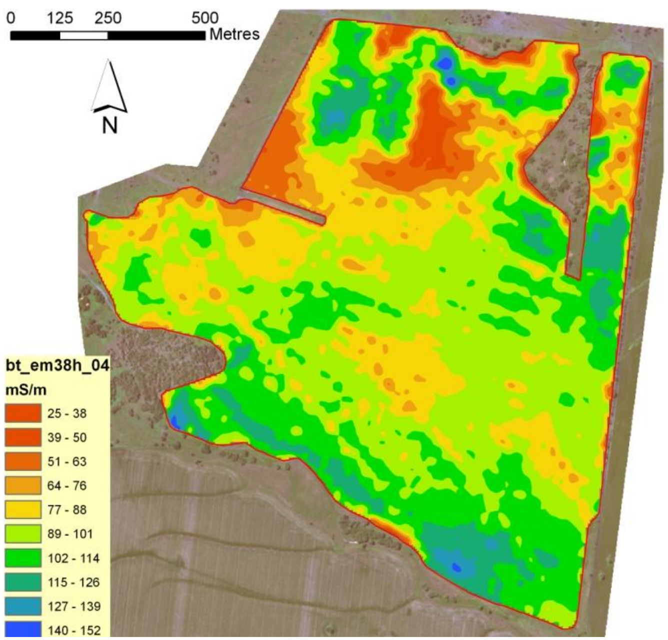
Operational savings from 'spot spraying' a variety of weeds over 4 seasons.

	Whole Farm
Seasons	4
Area sprayed	27388 ha
Average usage	17% per ha
Average rate	1.5 L/ha
Average cost	$5/ha
Average saving	$6.3/ha
Total saving	$172,544.00

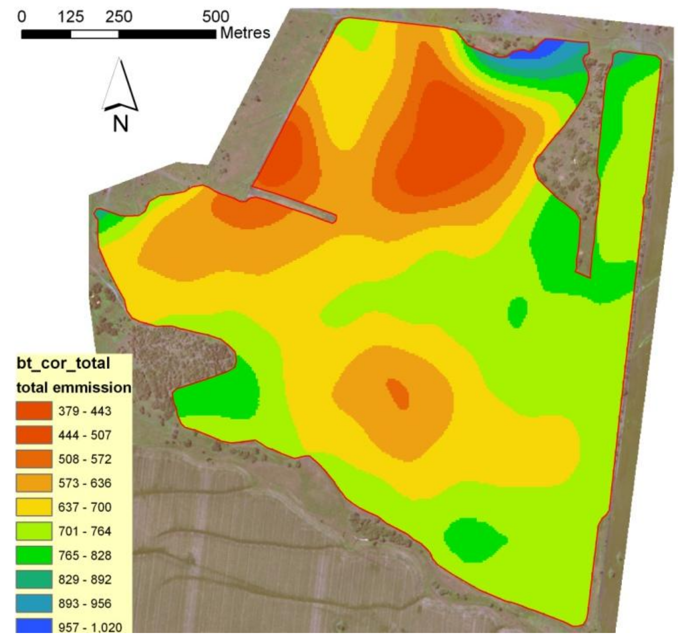
Data supplied by David Brownhill Merrilong Pastoral Company, Spring Ridge, NSW.

PRODUCTION VARIABILITY

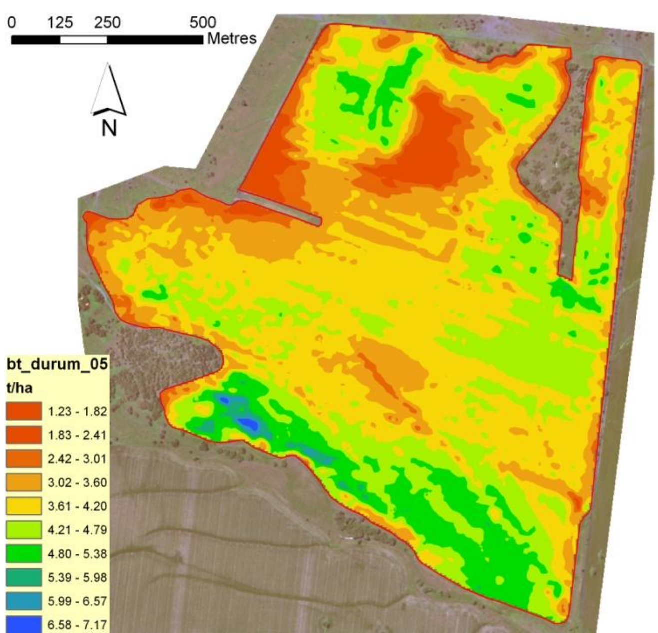
Soil ECa



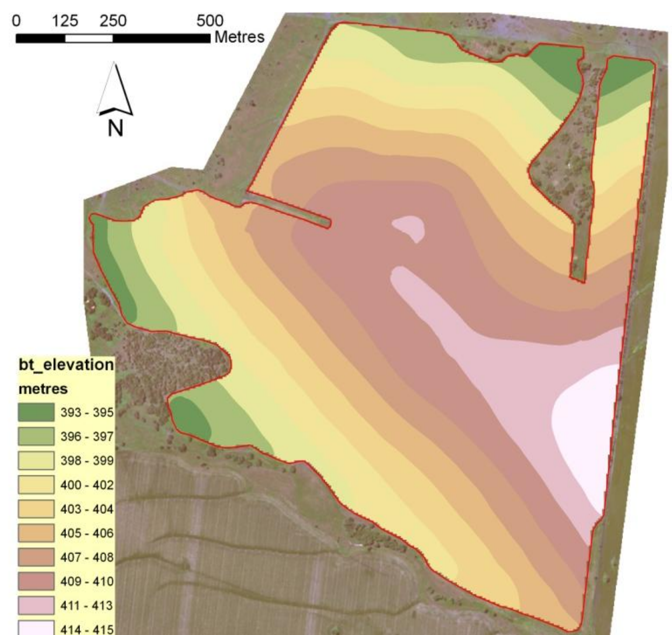
Gamma radiometrics



Crop Yield



Elevation and terrain information



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Site-specific crop management

Potential new nutrient management strategies

- **Readjustment of yield goals, either uniform or spatially variable.**
- **Nutrient replacement based on a sound understanding of spatial variability in resources and off-take.**
- **Optimal application based on spatial variation in measured response.**

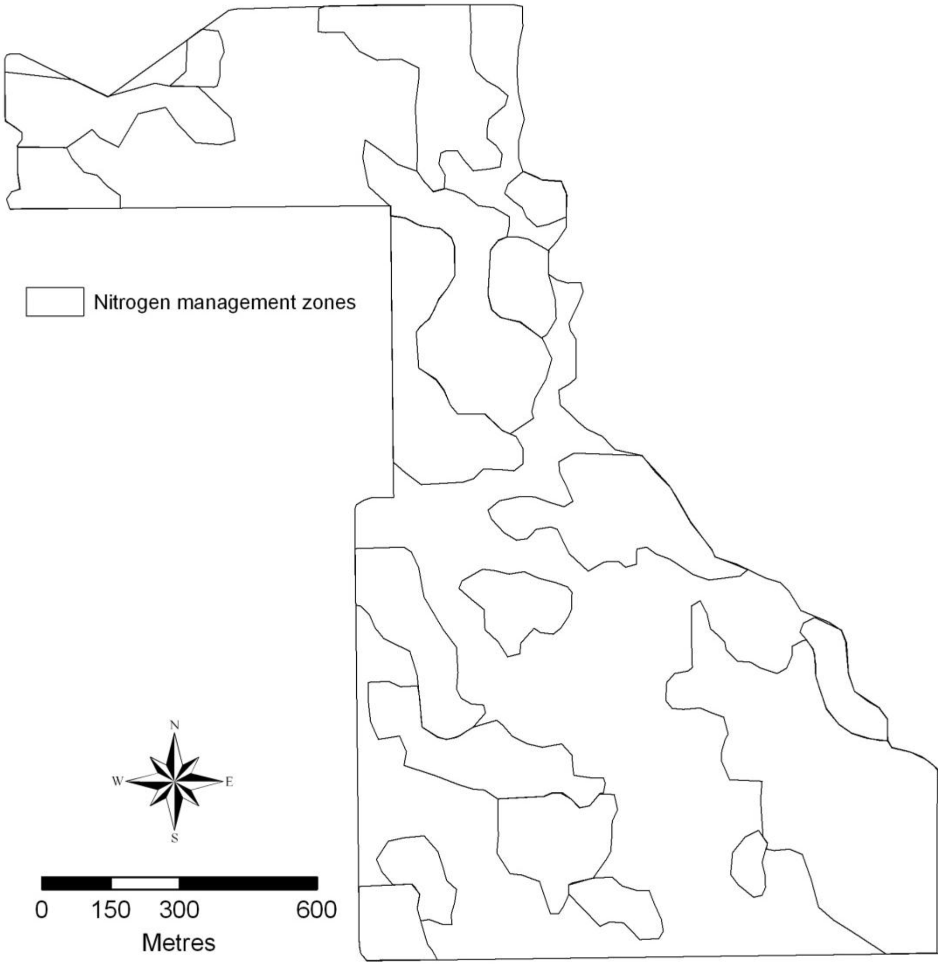
These could be based on a number of distinct management classes or on continuous variability.

Management classes

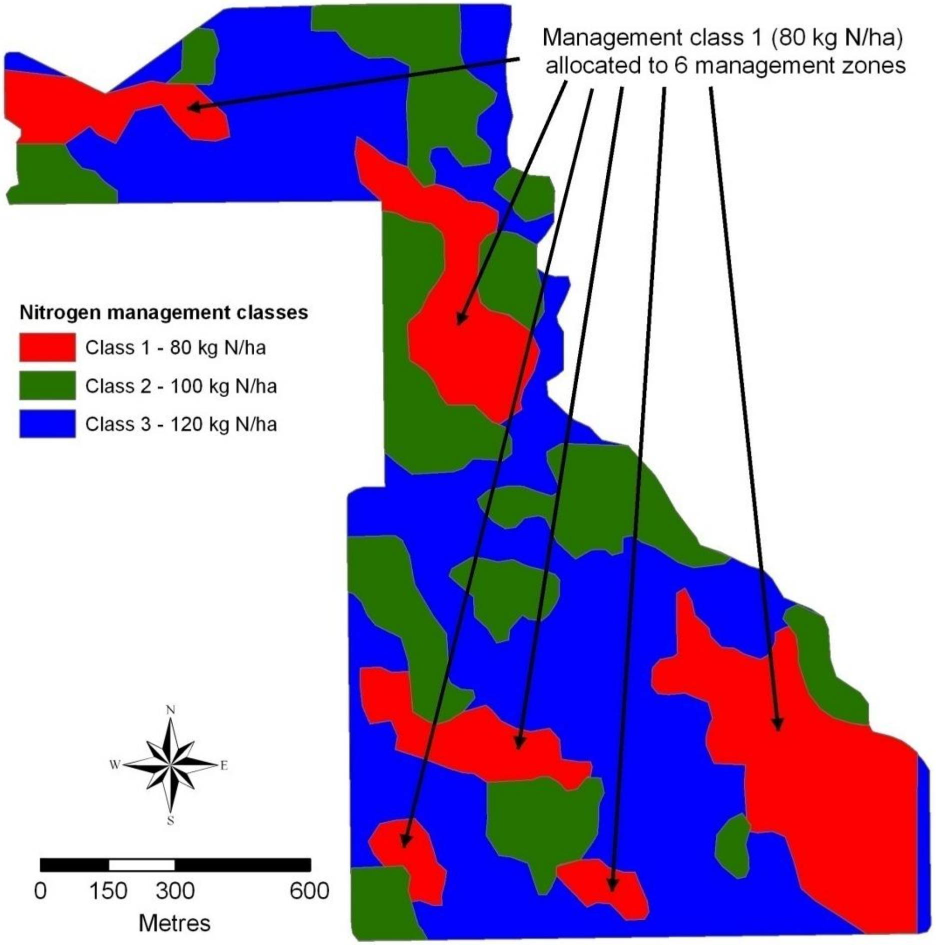
- A management class in SSCM is the total area for which a specific management requirement can be identified.
- Management classes are distinguished from each other based on the different requirements for management.
- A management zone is an unbroken area to which a specific management class treatment is applied.
- A management class may therefore be allocated to one or more management zones within field or farm.

Management classes and zones

Management zones

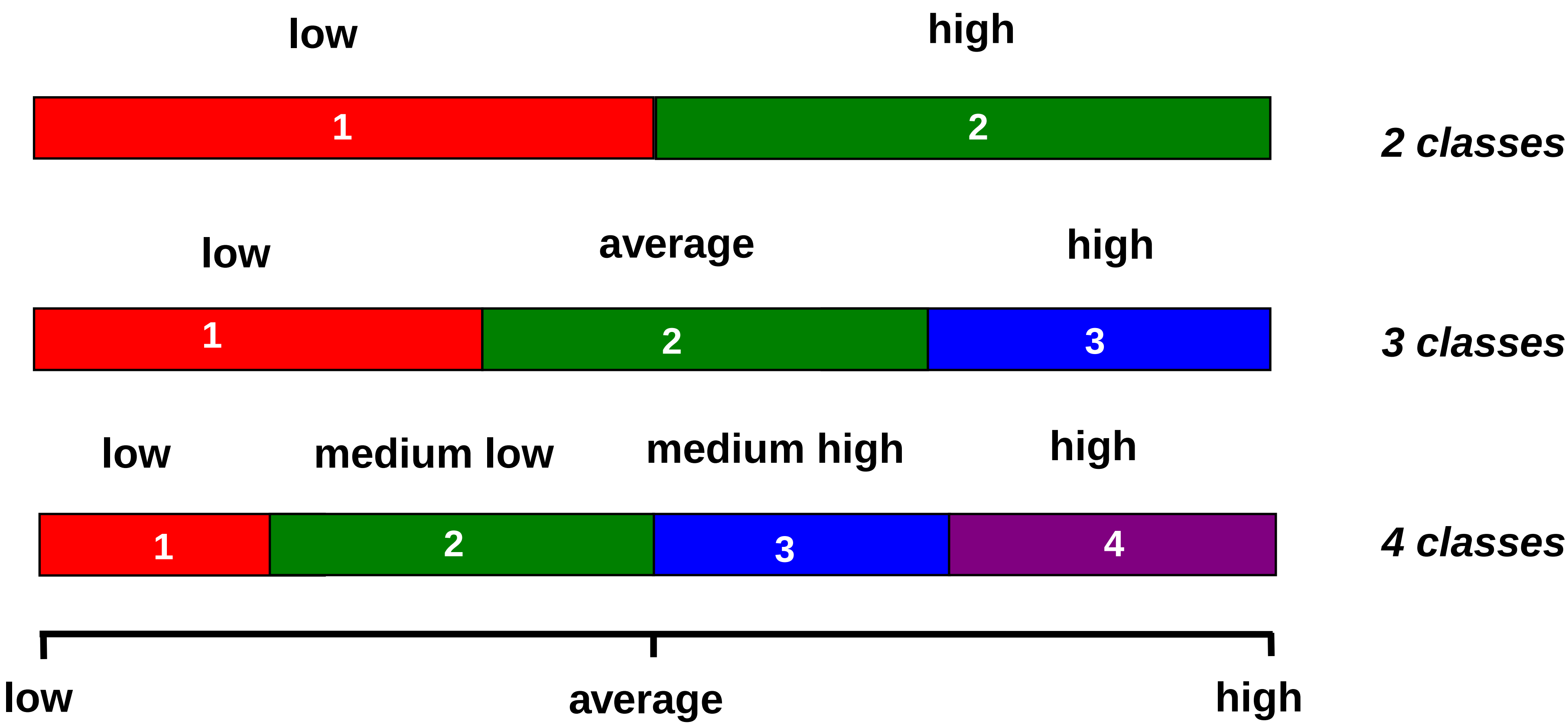


Management classes applied to management zones



Management classes

Production division with increasing class number



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Identifying useful management classes

Relevant Data Layers : (yield, soil ECa or γ, terrain information, reflectance)

↓

Spatial prediction onto a single grid using block kriging

↓

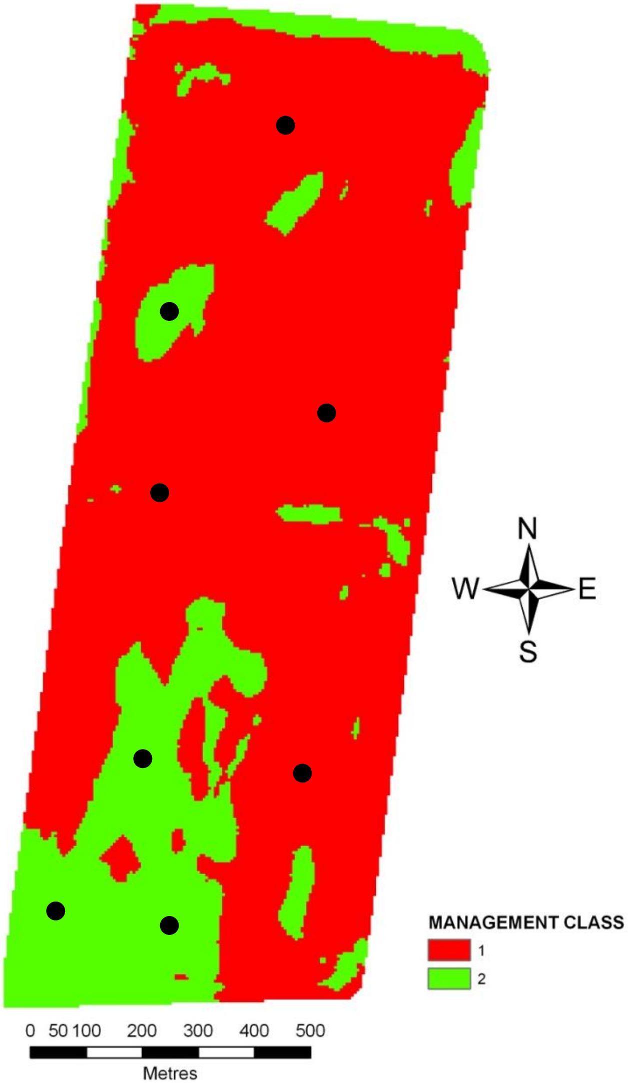
k-means clustering using all relevant layers to delineate production classes

↓

Utilise the mean kriging variance for yield to determine C.I. for class partitioning

Interrogate potential classes with directed sampling

Simple targeted sampling



Average P application 11kg P/ha

Soil P levels (mg/kg)

	Yr 1	***Yr 2***
Class 1	57	76
Class 2	27	35

Management changed to VRA for P fertiliser

Class 1 7 kg P/ha Class 2 20 kg P/ha

Soil P levels (mg/kg)

	Yr 1	***Yr 2***	***Yr 3***	***Yr 4***
Class 1	57	76	54	48
Class 2	27	35	28	52

A$35/ha improvement in gross margin over 2 years

Nutrient replacement

The amount of nutrient removed by a previous crop can be calculated using a yield map and a formula relating to the amount of nutrient exported per tonne of grain. e.g.:

$$P\ removed_{(kg\ P/ha)} = 4_{(kg\ P/t)} \times wheat\ yield_{(t/ha)}$$

- **The resulting data can be used to make a map of phosphorus replacement rates in the field.**
- **However, it does not allow any margin for error in the estimate of how much phosphorus is removed per ton of grain, nor the possibility that a base level of phosphorus may be required in the initial stages of crop growth.**
- **An alternative is to include a base application.**

$$P\ removed_{(kg\ P/ha)} = 5_{(kg\ P/t)} + 4_{(kg\ P/t)} \times wheat\ yield_{(t/ha)}$$

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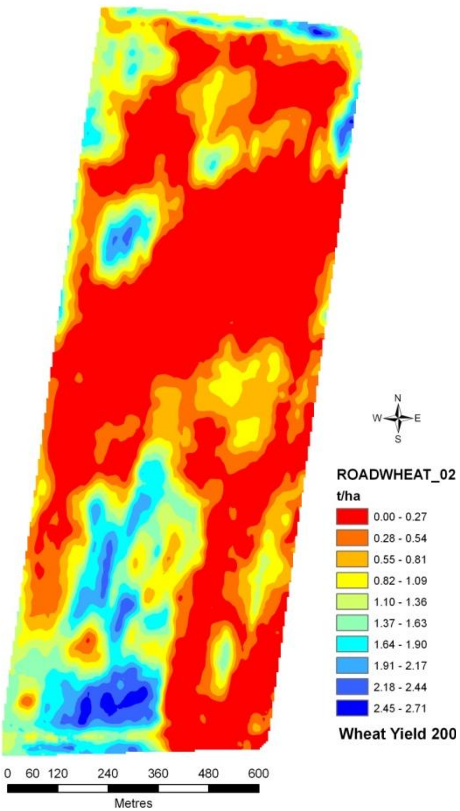
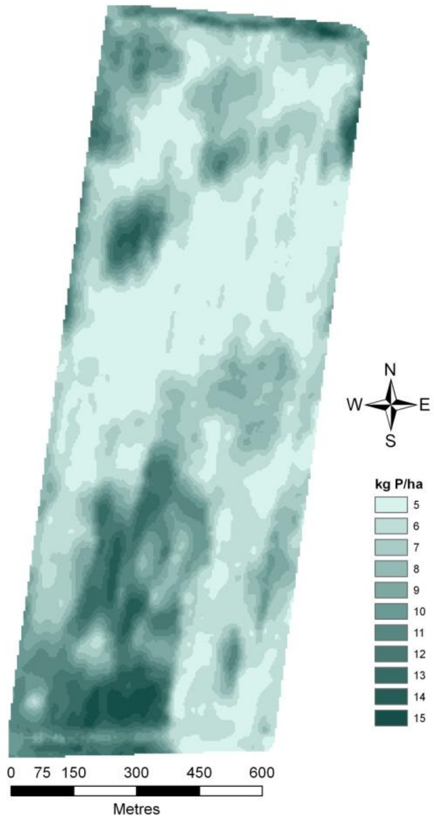
Nutrient replacement

Used in map-based whole field VRA

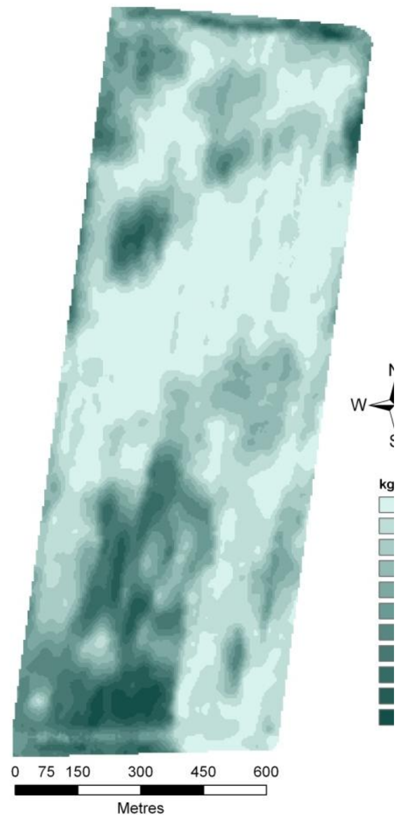
Used in map-based management class VRA



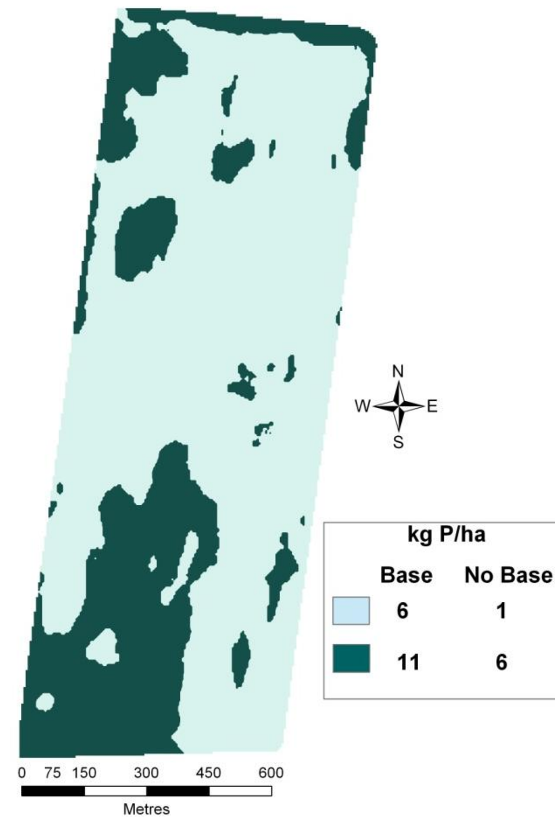
wheat yield map



Phosphorus removed map



Phosphorus removed plus a base rate



2 class Phosphorus replacement map

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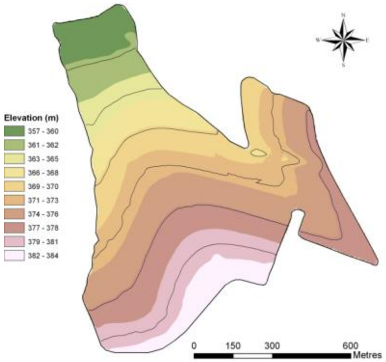
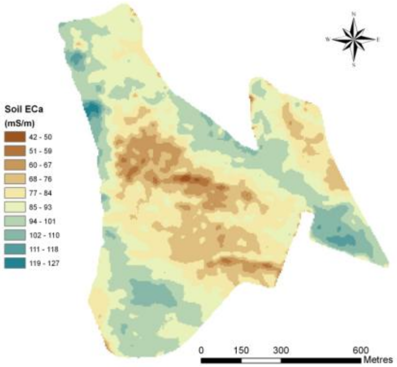
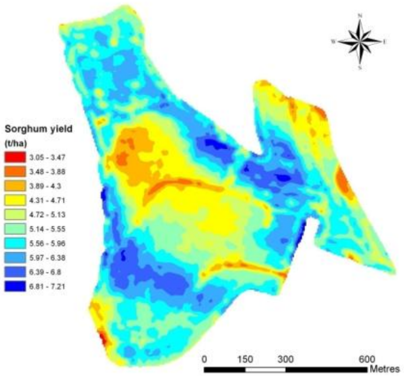
Uniform yield goal



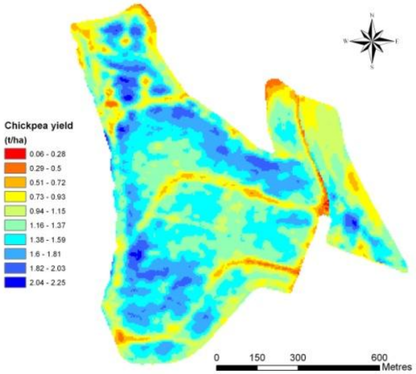
elevation



soil electrical conductivity



sorghum yield

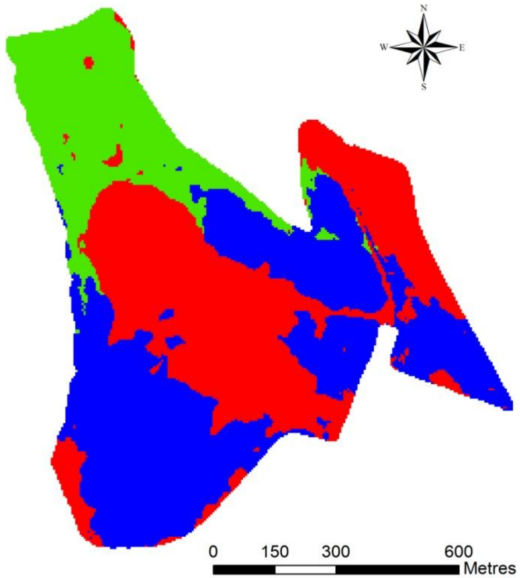


chickpea yield

=

3 PMC

1
2
3



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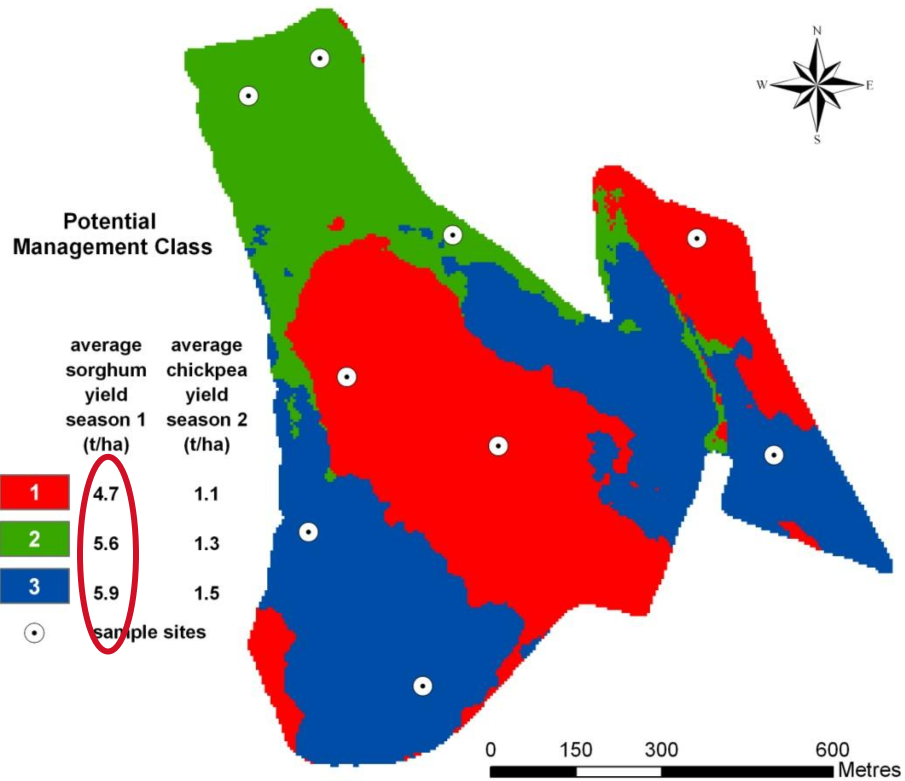
Uniform yield goal



Investigative samples directed into 3 potential management classes

	Class1 (red)	Class 2 (green)	Class 3 (blue)	Field mean
Sorghum yield (t/ha)	4.7	5.6	5.9	5.4
Topsoil nitrate (mg/kg)	30.4	19.3	10.6	20.1

identify differences in soil nitrate levels

What may be happening here?

Differences in production distinguished between the classes

Uniform yield goal

Calculating input requirement based on uniform yield/quality goals

Total Nitrogen Requirement	=	Yield Goal	X	Protein Goal	X	1.75	X	2
205 kg N/ha	=	4.5	X	13	X	1.75	X	2

N applications based on satisfying the uniform N requirement

	Class1 (red)	Class 2 (green)	Class 3 (blue)	Field mean
Area (ha)	29	13	33	75
Measured soil nitrate N (kg N/ha)	238	172	87	165
Uniform N application based on field mean soil nitrate (kg N/ha)	40	40	40	40
VRA N application based on measured soil N (kg N/ha)	0	33	118	58

Uniform yield goal

Calculating input requirement based on uniform yield/quality goals

	Class1 (red)	Class 2 (green)	Class 3 (blue)	Field mean
Area (ha)	29	13	33	75
Measured soil nitrate N (kg N/ha)	238	172	87	165
Uniform N application based on field mean soil nitrate (kg N/ha)	40	40	40	40
VRA N application based on measured soil N (kg N/ha)	0	33	118	58

Class1 Urea Waste = 40 kg N/ha x 29 ha x 2.17 = 2521 kg

Class2 Urea Waste = 7 kg N/ha x 13 ha x 2.17 = 198 kg

Total Urea Waste = 2.7 tonnes x 600/t = $1620 = $22/ha

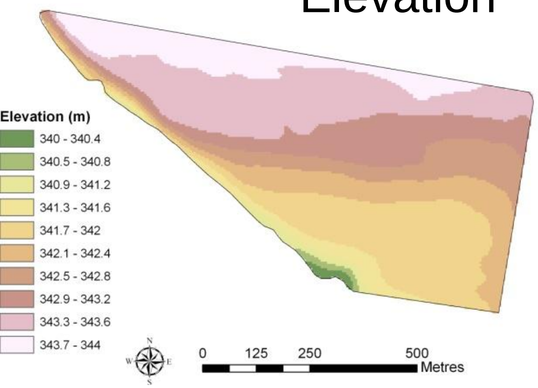
Fertiliser shortfall = 66% in Class3

What might be the implications of the shortfall?

Adjust yield goals

Calculating input requirement based on adjusting yield/quality goals

Elevation



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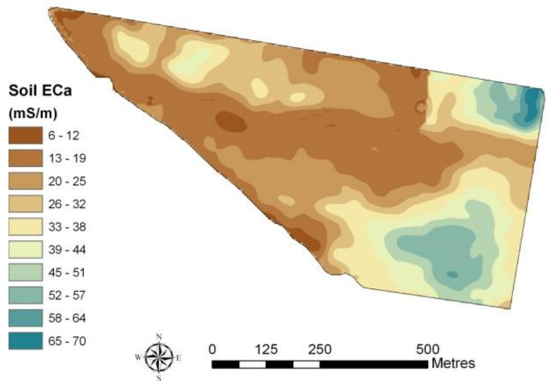
Soil ECa



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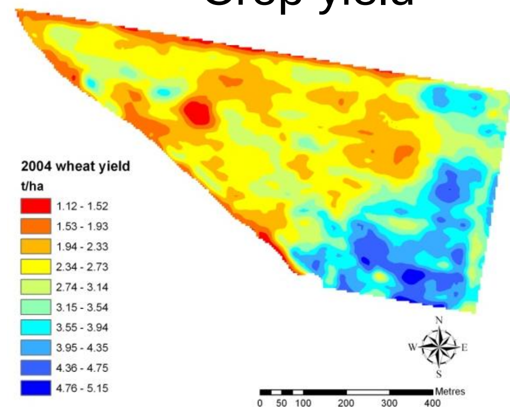
Crop yield



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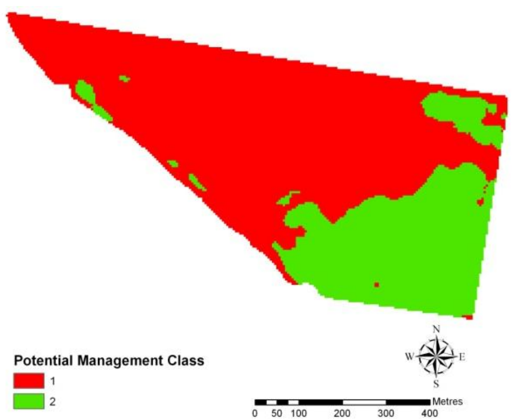

2 PMC

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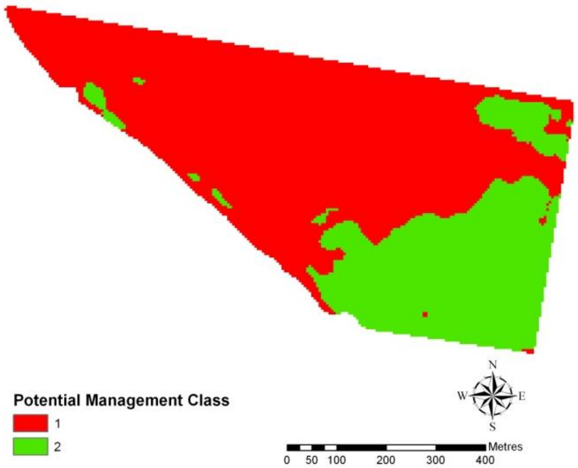
Adjust yield goals

Calculating input requirement based on adjusting yield/quality goals

Class	Average wheat yield (t/ha)		
	season 1	season 2	combined
1	2.4 (0.004)	2.6 (0.006)	2.5
2	3.8 (0.007)	3.2 (0.007)	3.5
Whole field	2.9 (0.006)	2.8 (0.005)	2.9
Difference between class 1 and 2 (%)	37	19	28



Yield differences between the two classes over subsequent seasons

Numerous ways a manager could use this information to adjust management

Adjust yield goals

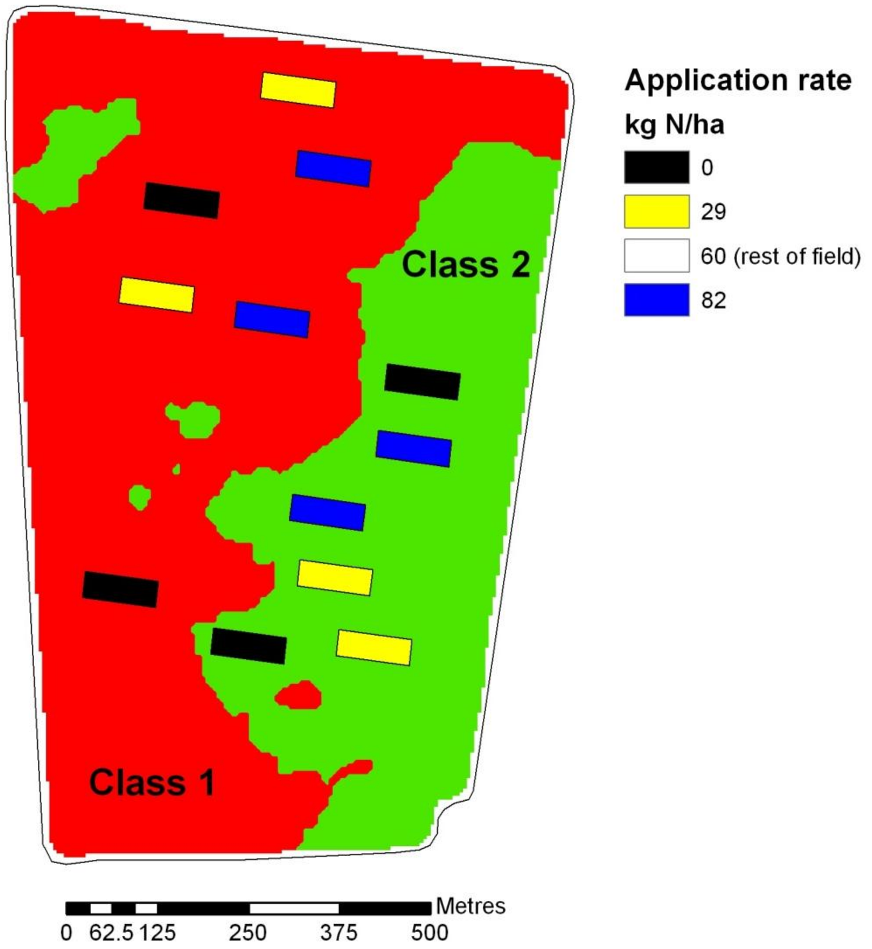
Calculating input requirement based on adjusting yield/quality goals

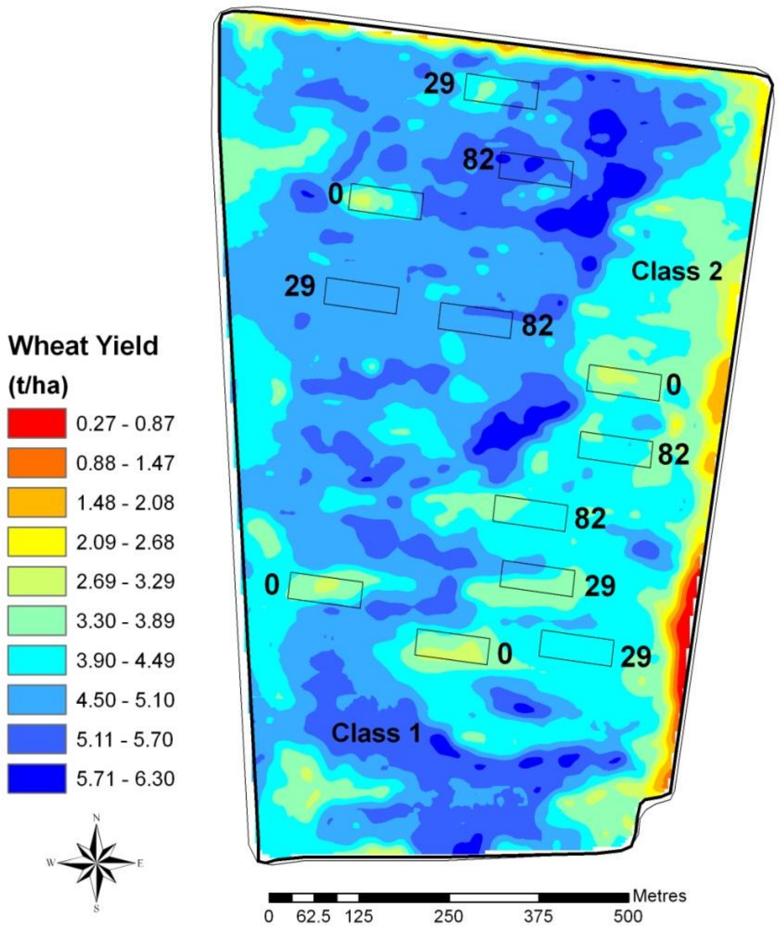
Total Nitrogen Requirement	=	Yield Goal	X	Protein Goal	X	1.75	X	2	
160 kg/ha	=	3.5	X	13	X	1.75	X	2	X 40 ha = 6.40 t
114 kg/ha	=	2.5	X	13	X	1.75	X	2	X 27 ha = 3.08 t
160 kg/ha	=	3.5	X	13	X	1.75	X	2	X 13 ha = 2.08 t

Using Class-specific yield goals in this manner saves:
1.24 t x 2.17 x $600 = $1614 ($40/ha)

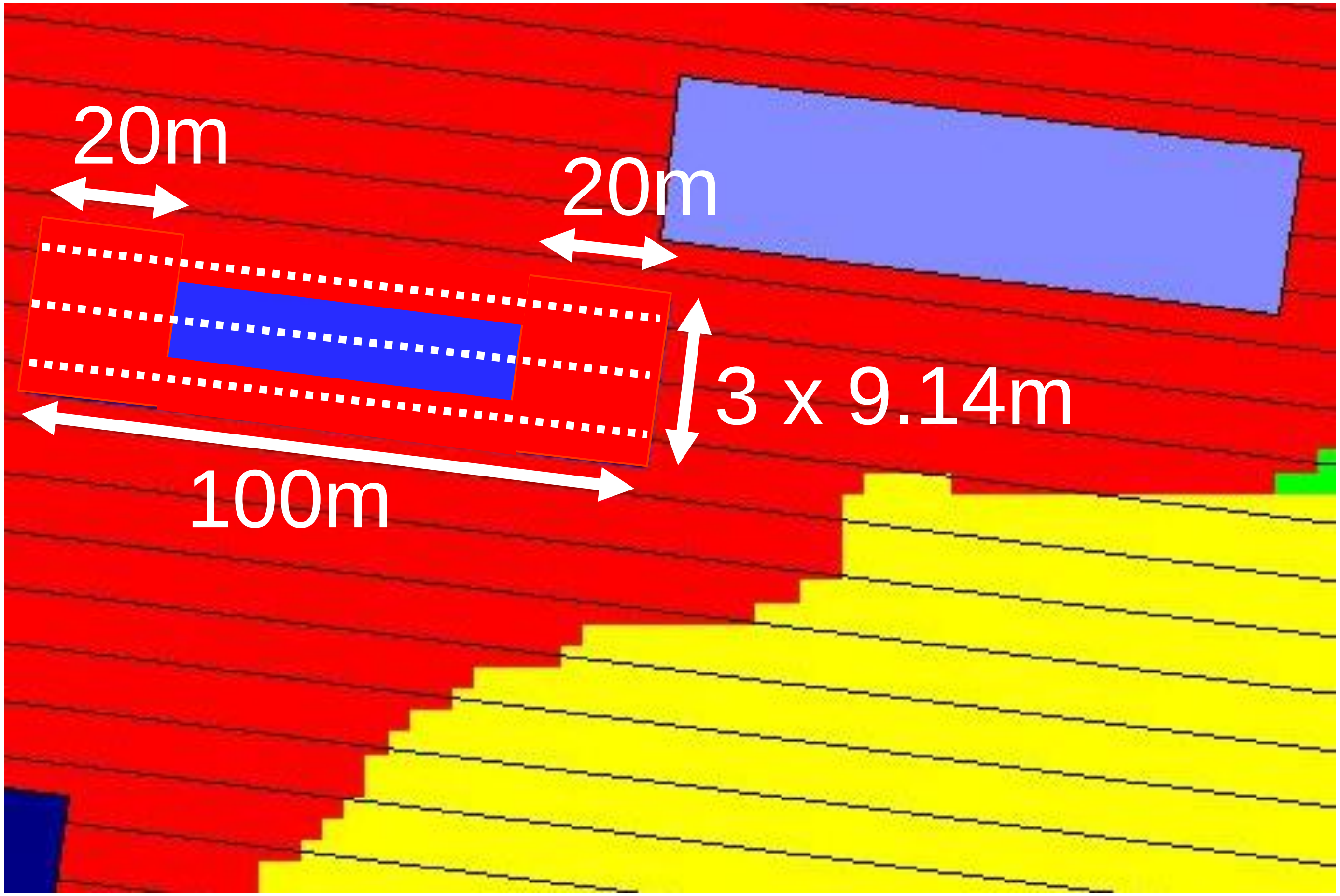
Rate response experiments

Experimental design



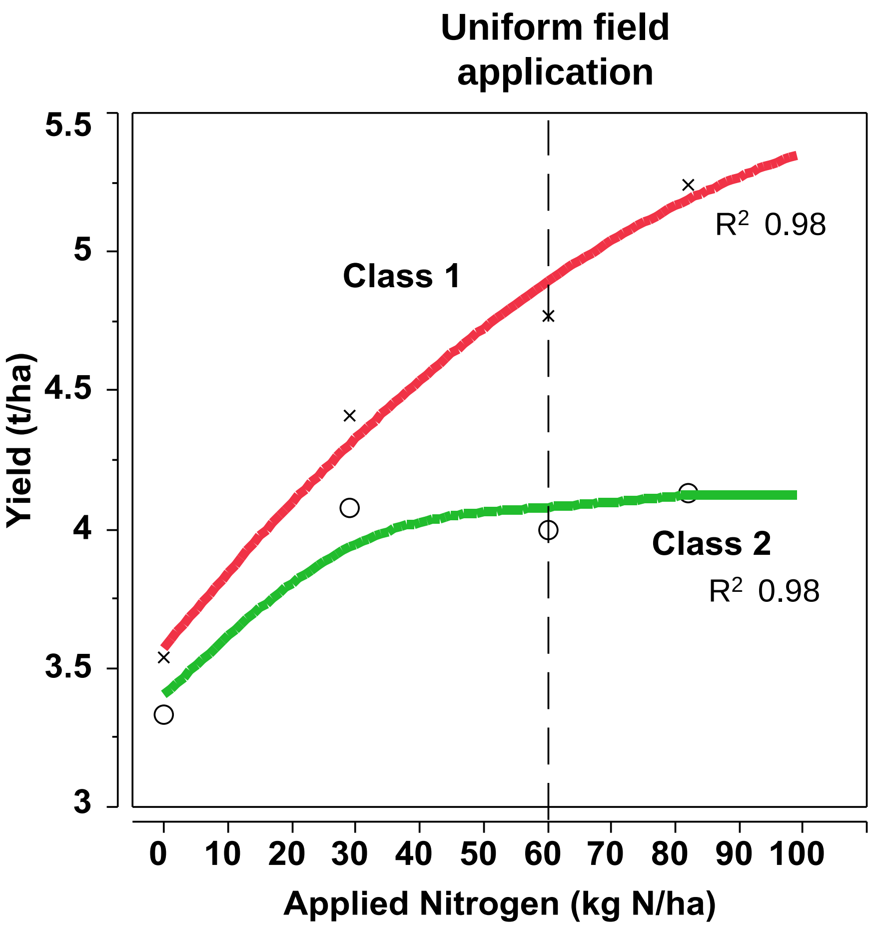


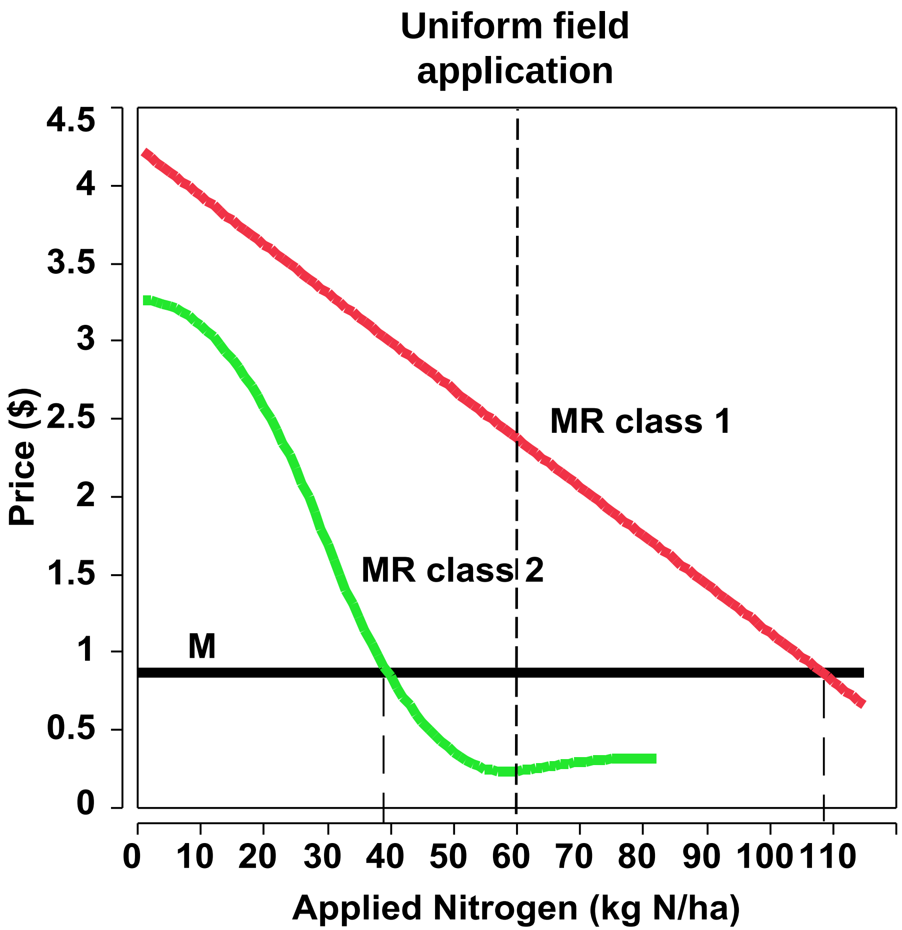
Rate response experiments



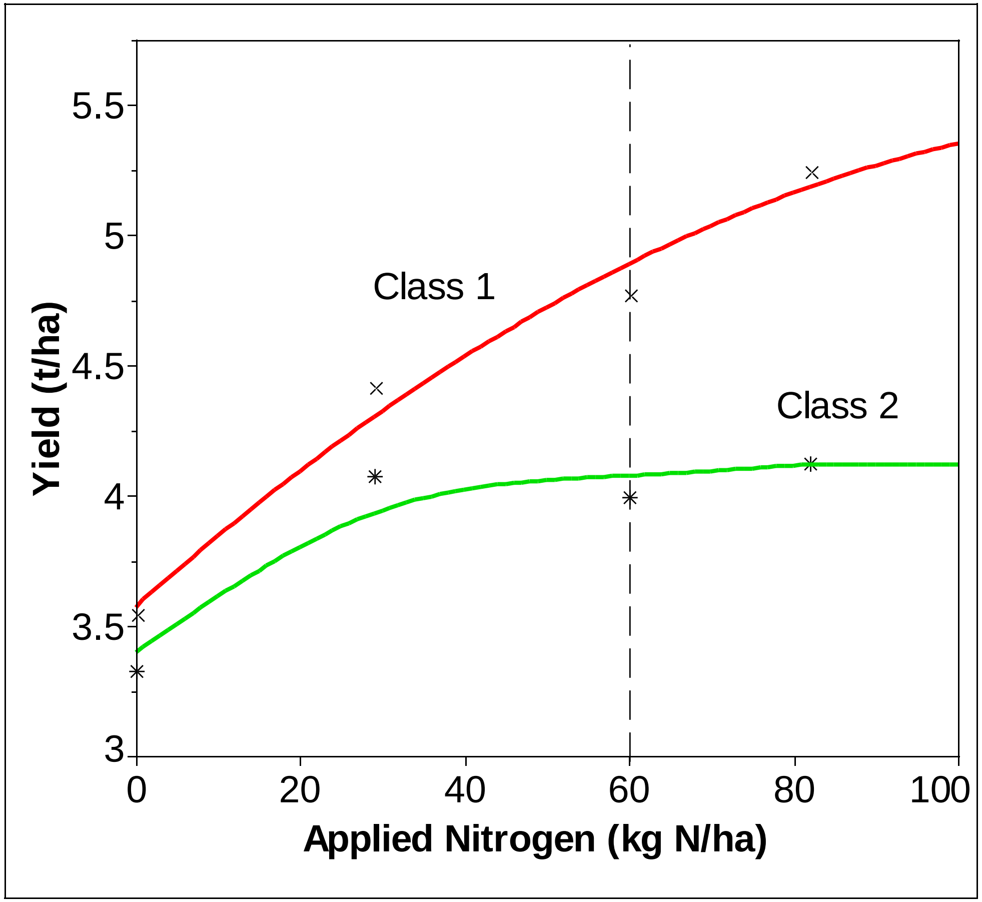
- Ends removed before analysis to remove grain blending
- Central cut used for final analysis depending on treatment

Rate response experiments





Rate response experiments



- **Paddock Average Application = 60kg N applied as BigN**
- **Optimum**
  Class 1 = 100kg N
  Class 2 = 39 kg N
- **Scenario 1: maintain the total amount of fertiliser applied to the paddock but move the overapplication on Class 2 to class 1**
  = Improved gross margin of $11.50/ha.
- **Scenario 2: apply correct amount to each Class**
  = Improved gross margin of $25/ha.

Field-scale P fertiliser experiments

Year	Size (ha)	Crop	Yield (t/ha)	Net Wastage ($/ha)	Proportion of season P fertiliser costs (%)
2003	40	Wheat	4.4	55	93
2003	110	Wheat	2.2	36	129
2004	34	Wheat	1.8	50	85
2004	40	Faba Beans	2.0	50	85
2004	110	Field peas	1.0	8	30
2005	34	Barley	4.5	39	74
2005	39	Wheat	4.3	61	105
2005	40	Wheat	5.6	24	43
2005	110	Wheat	3.1	65	236
2006	55	Wheat	0.9	36	78
2006	110	Barley	1.0	33	121
2007	39	Wheat	1.5	103	177
2007	43	Canola	0.9	58	169
2007	55	Canola	0.5	18	53
2007	91	Wheat	1.1	45	154
2008	39	Wheat	1.4	59	140
2008	43	Wheat	2.3	77	189
2008	55	Wheat	1.2	26	40
Minimum	34			8 $/ha	30 %
Median	43			48 $/ha	99 %
Maximum	110			103$t/ha	236 %

Comparison of gross margin between field average and optimum rate management

Net wastage calculated on a fertiliser and yield basis

Net wastage standardised to the investment in fertiliser each year to cover yearly price fluctuations.

Field-scale N fertiliser experiments

Year	Size (ha)	Crop	Yield (t/ha)	Net Wastage ($/ha)	Proportion of season N fertiliser costs (%)
2003	47	Wheat	4.8	4	12
2003	50	Wheat	3.2	48	372
2003	130	Canola	2.3	12	30
2004	22	Canola	1.7	79	143
2004	43	Wheat	3.3	46	130
2004	50	Barley	2.4	7	53
2004	79	wheat	4.5	25	45
2004	80	wheat	4.9	15	26
2004	130	Wheat	2.5	39	97
2005	43	Barley	2.5	28	80
2005	130	Barley	4.4	74	177
2006	50	Wheat	2.0	51	334
2006	130	Canola	0.4	20	43
2008	97	Wheat	3.5	103	240
2008	130	Barley	2.5	78	115
Minimum	22			4 $/ha	12 %
Median	79			39 $/ha	97 %
Maximum	130			103 $/ha	372 %

Comparison of gross margin between field average and optimum rate management

Net wastage calculated on a fertiliser and yield basis

Net wastage standardised to the investment in fertiliser each year to cover yearly price fluctuations.

THE UNIVERSITY OF SYDNEY

Comparison of gross margin between field average and optimum rate management

Potential wastage (fertiliser and yield)

$$\text{Proportion of fertiliser costs (\%)} = \frac{\text{nett wastage (\$)}}{\text{fertiliser bill (\$)}} \times 100$$

	Minimum	Median	Maximum
Size (ha)	34	43	110
Yield (t/ha)	0.5	1.7	5.6
Net Wastage ($/ha)	8	48	103
Proportion of seasonal P fertiliser costs (%)	30	99	236

Phosphorus

$48/ha

or

99% of P fertiliser costs

	Minimum	Median	Maximum
Size (ha)	22	79	130
Yield (t/ha)	0.4	2.5	4.9
Net Wastage ($/ha)	4	39	103
Proportion of seasonal N fertiliser costs (%)	12	97	372

Nitrogen

$39/ha

or

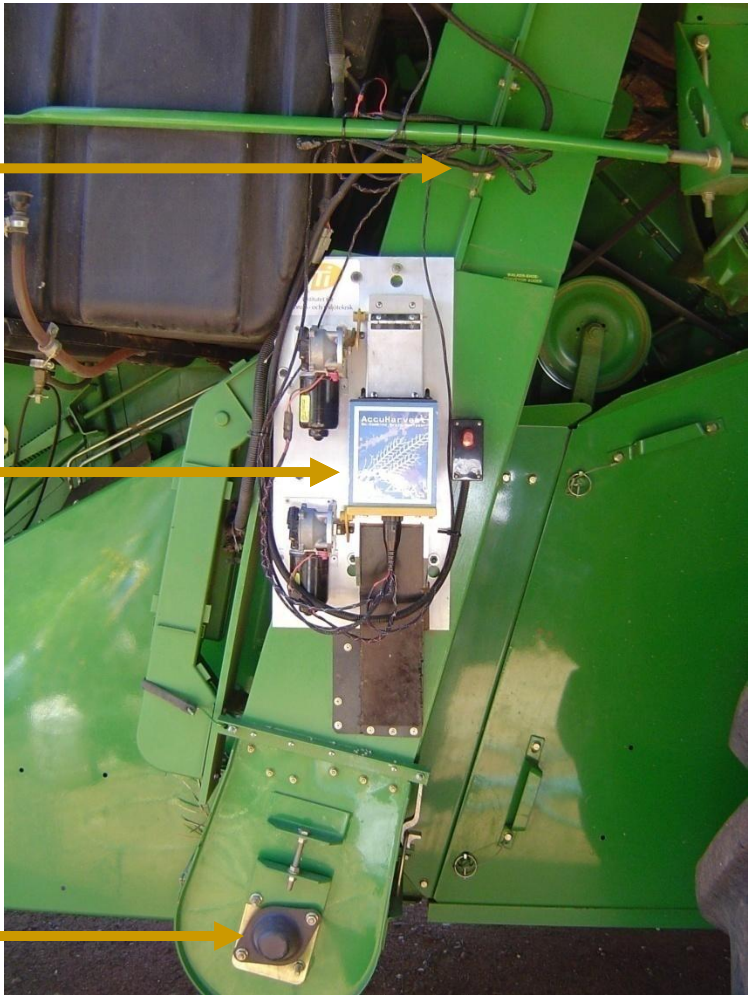
97% of N fertiliser costs

Protein monitor.

Clean Grain Elevator

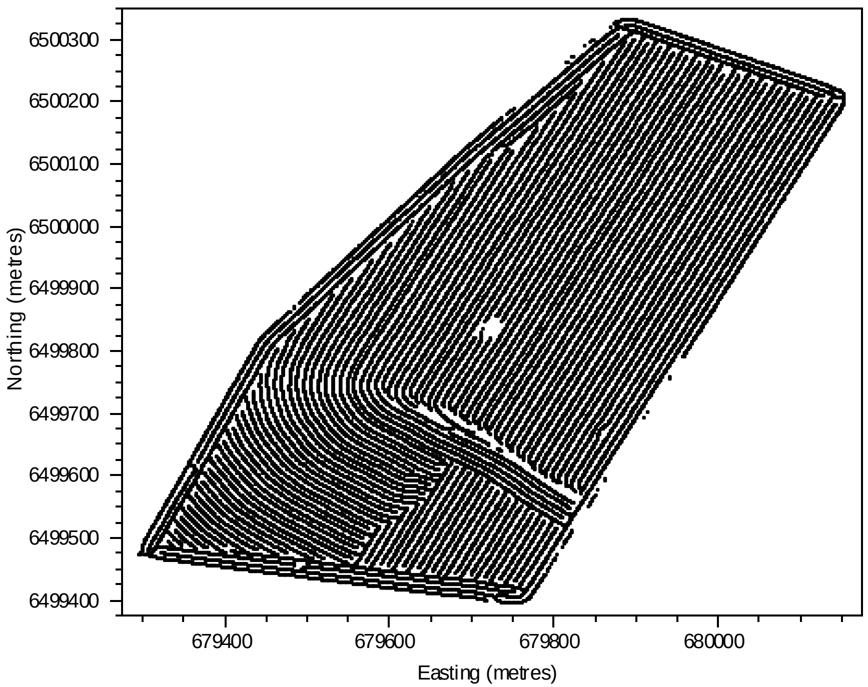
Protein Sensor

Cross Auger

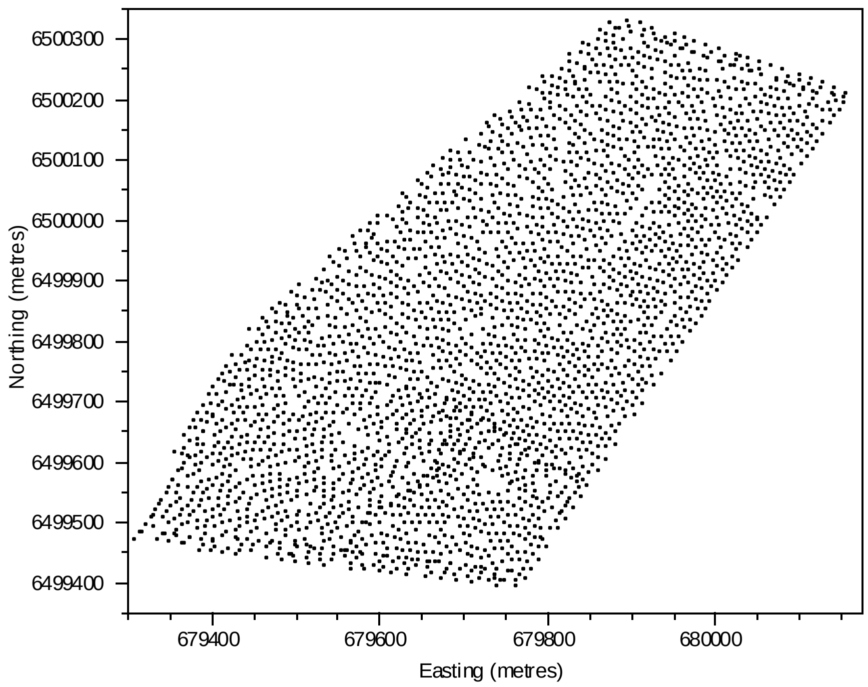


Data density comparison

Yield Sensor Data



Protein Sensor Data



Data density comparison

Yield Sensor Data

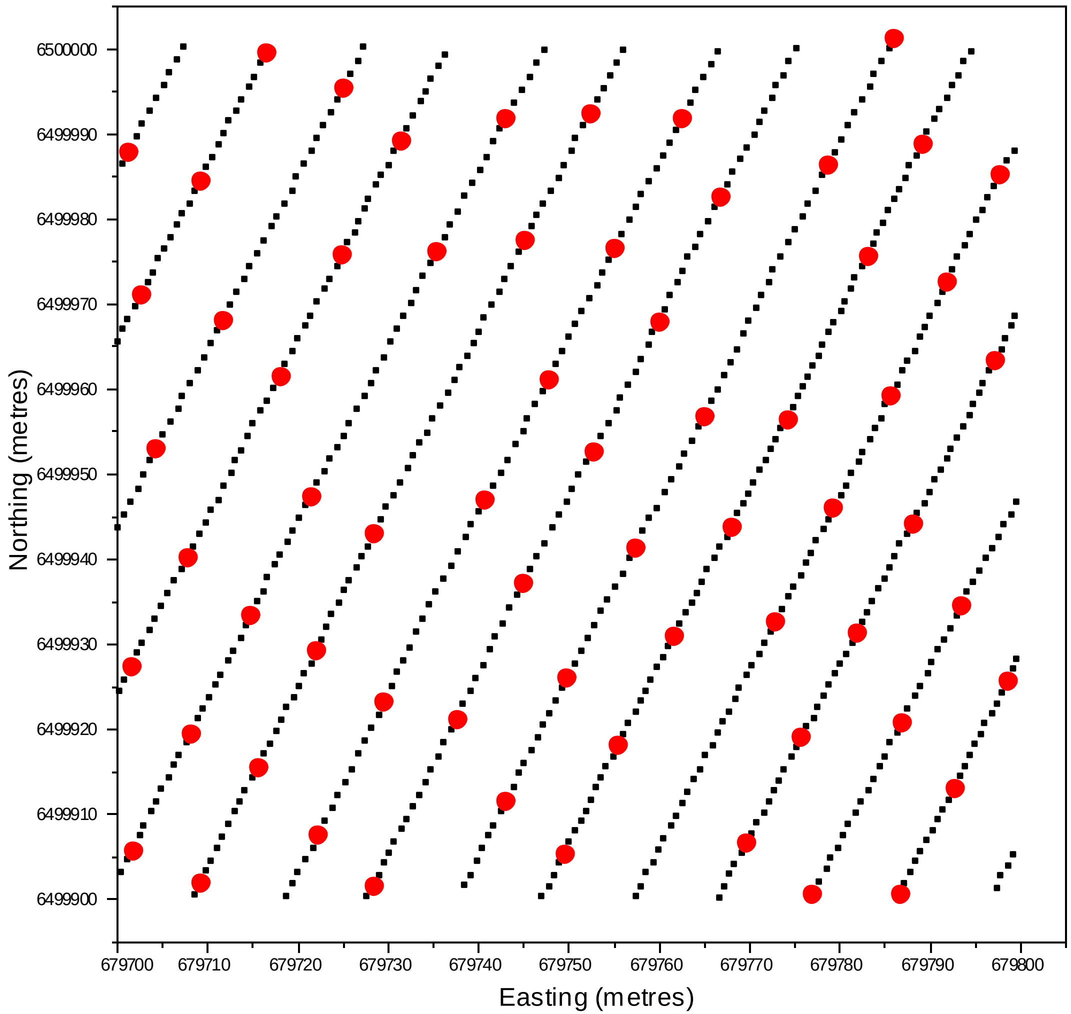
725/ha

(1 second cycle)

Protein Sensor Data

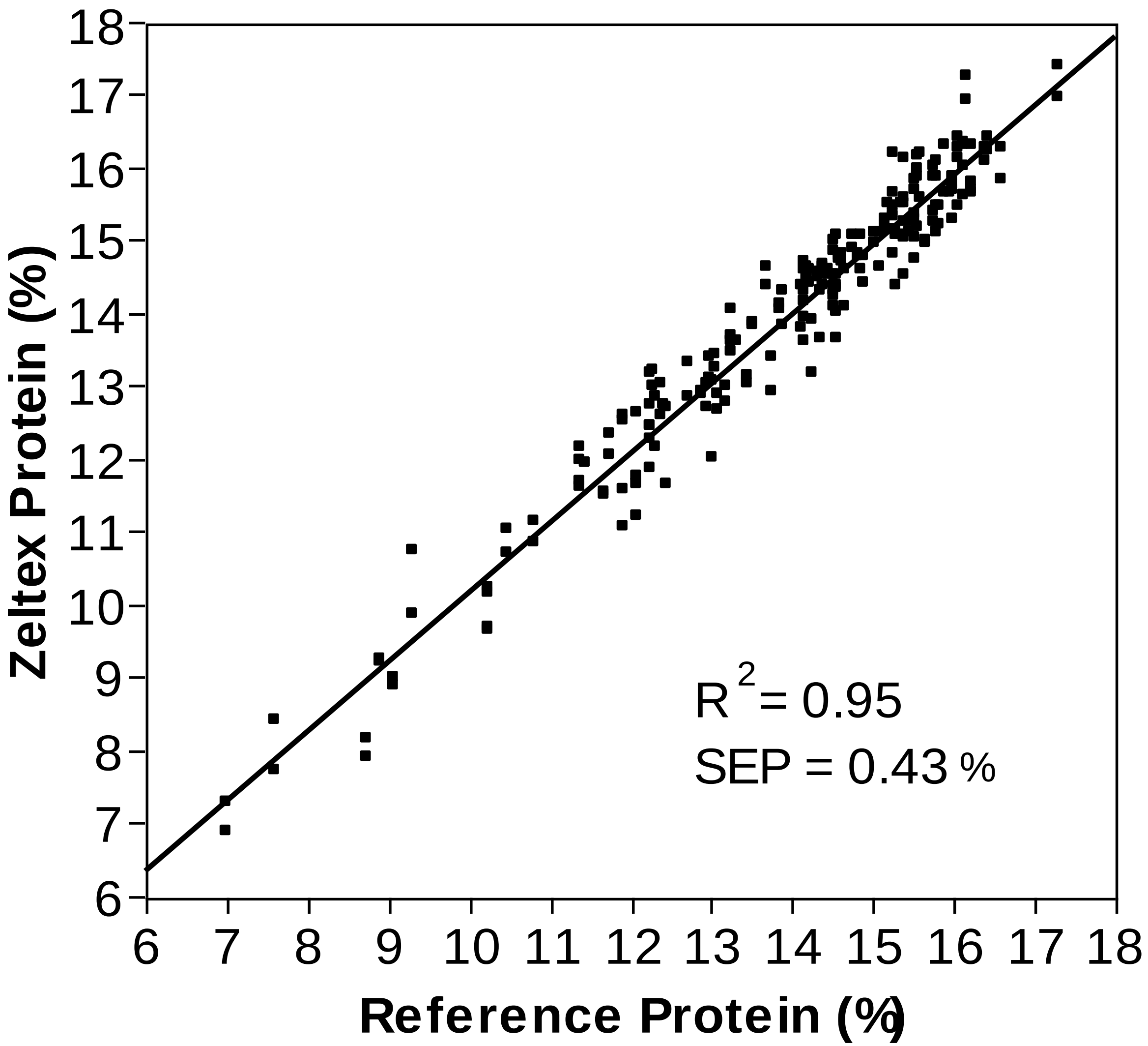
65/ha

(~12 second cycle)

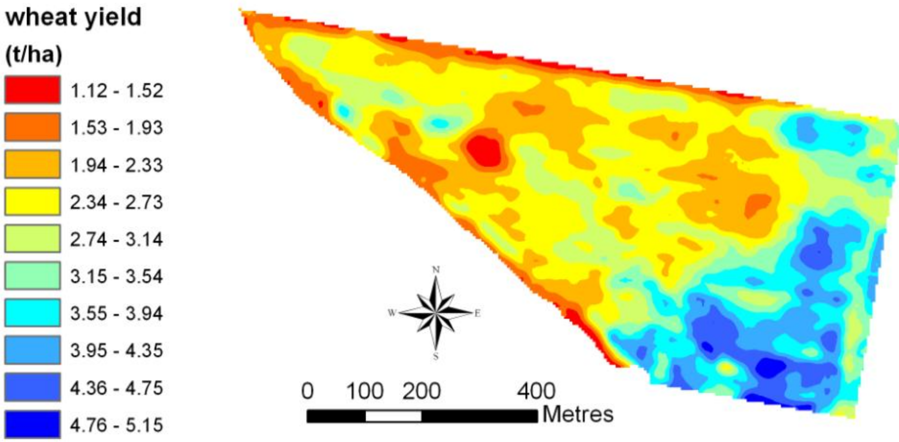


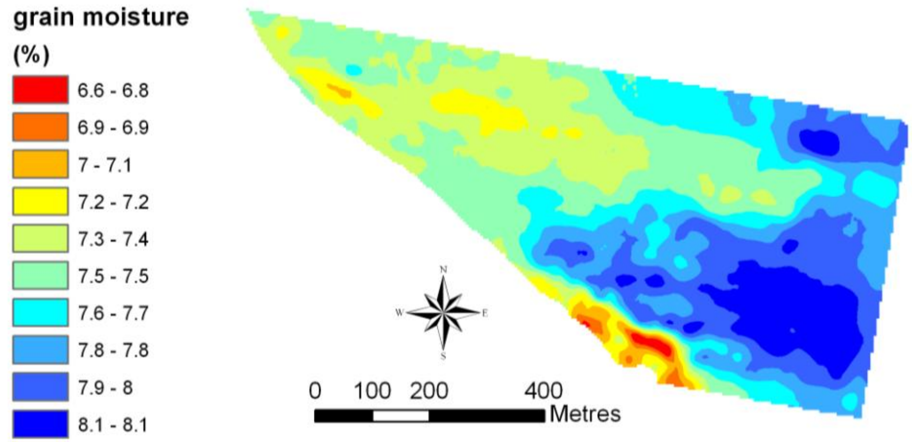
Linear calibration

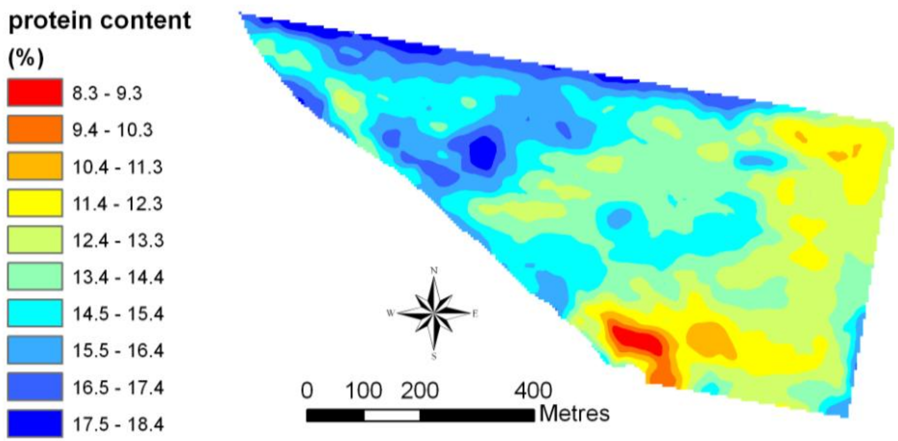
With a linear calibration it is relatively simple to adjust a calibration for slope and bias



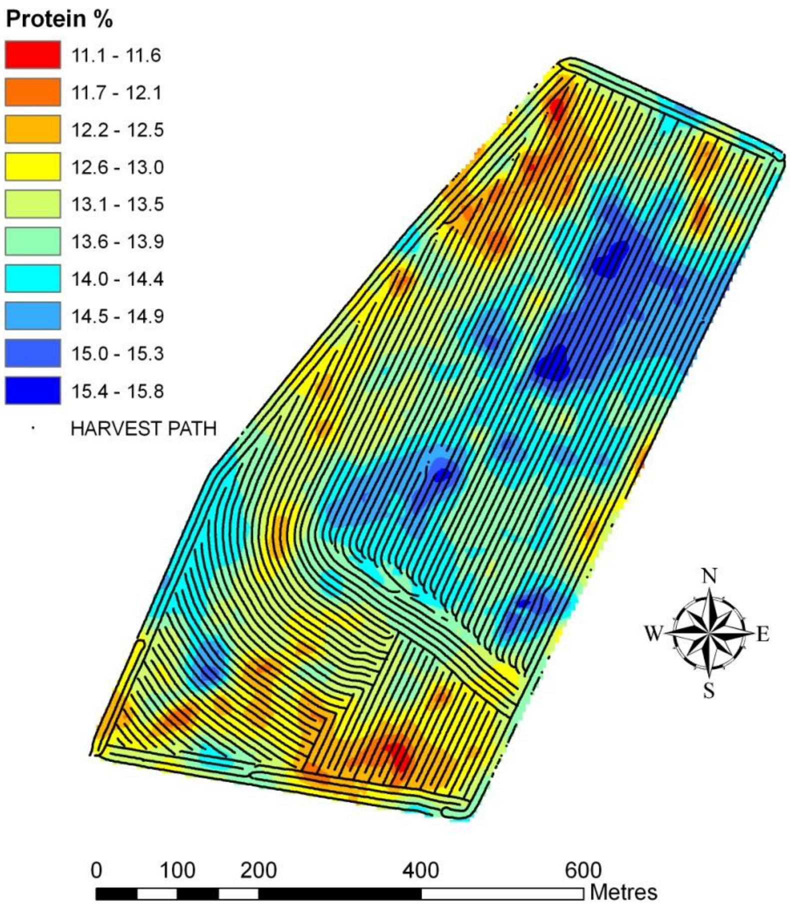
Grain yield, moisture and protein - wheat





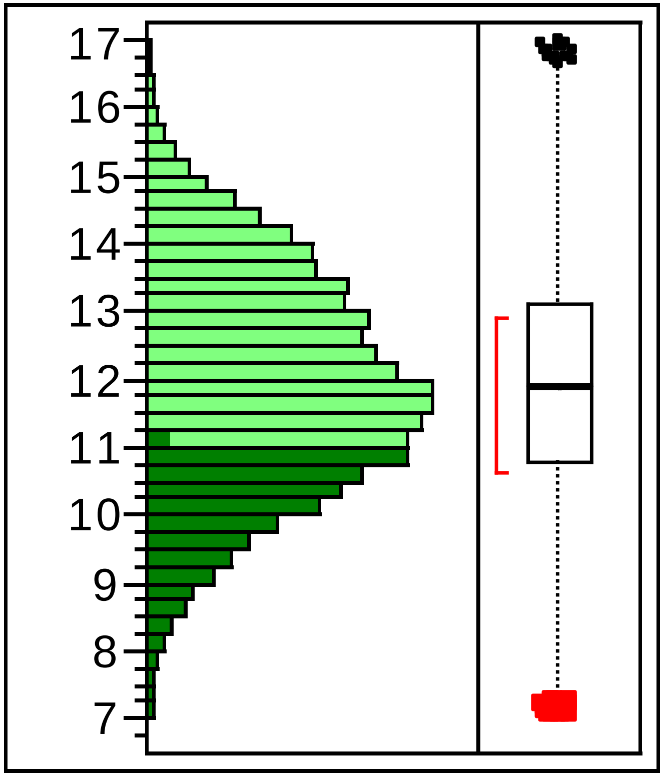


Differential harvesting



Seeking low protein wheat for a flat-grade

Differential harvesting



600 tonne fixed grade

plus

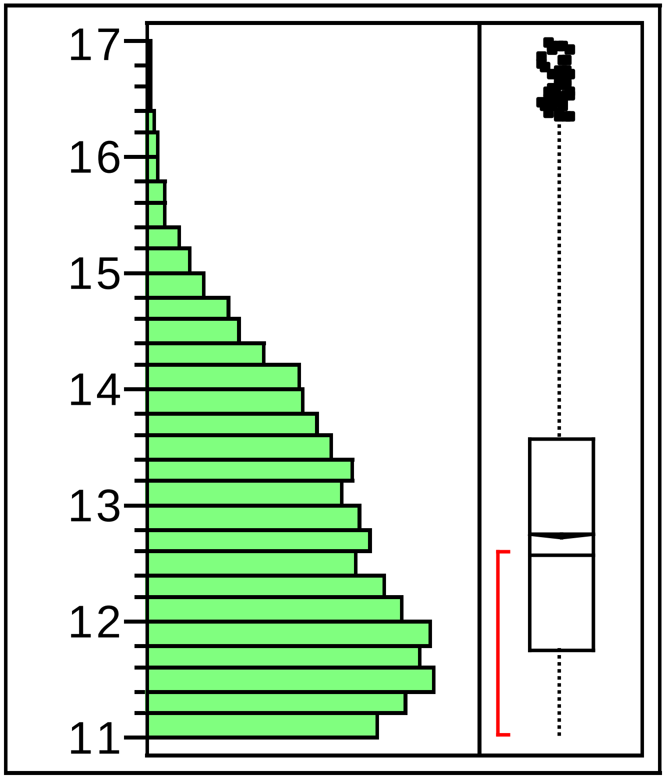
1400 tonne pooled

=

2000 tonne production

mean: 11.9% protein

Differential harvesting



mean: 12.8% protein

$1.53 per 0.1% protein

$1.53 X 9 = $13.80/t

$13.80 X 1400 t = $19,320

Information about the variability that is present in a production system is *VALUABLE*

What is done about it dictates the *EXTENT OF THE VALUE*