Precision Agriculture:

Data-Driven Decisions

for the

Business of Farming

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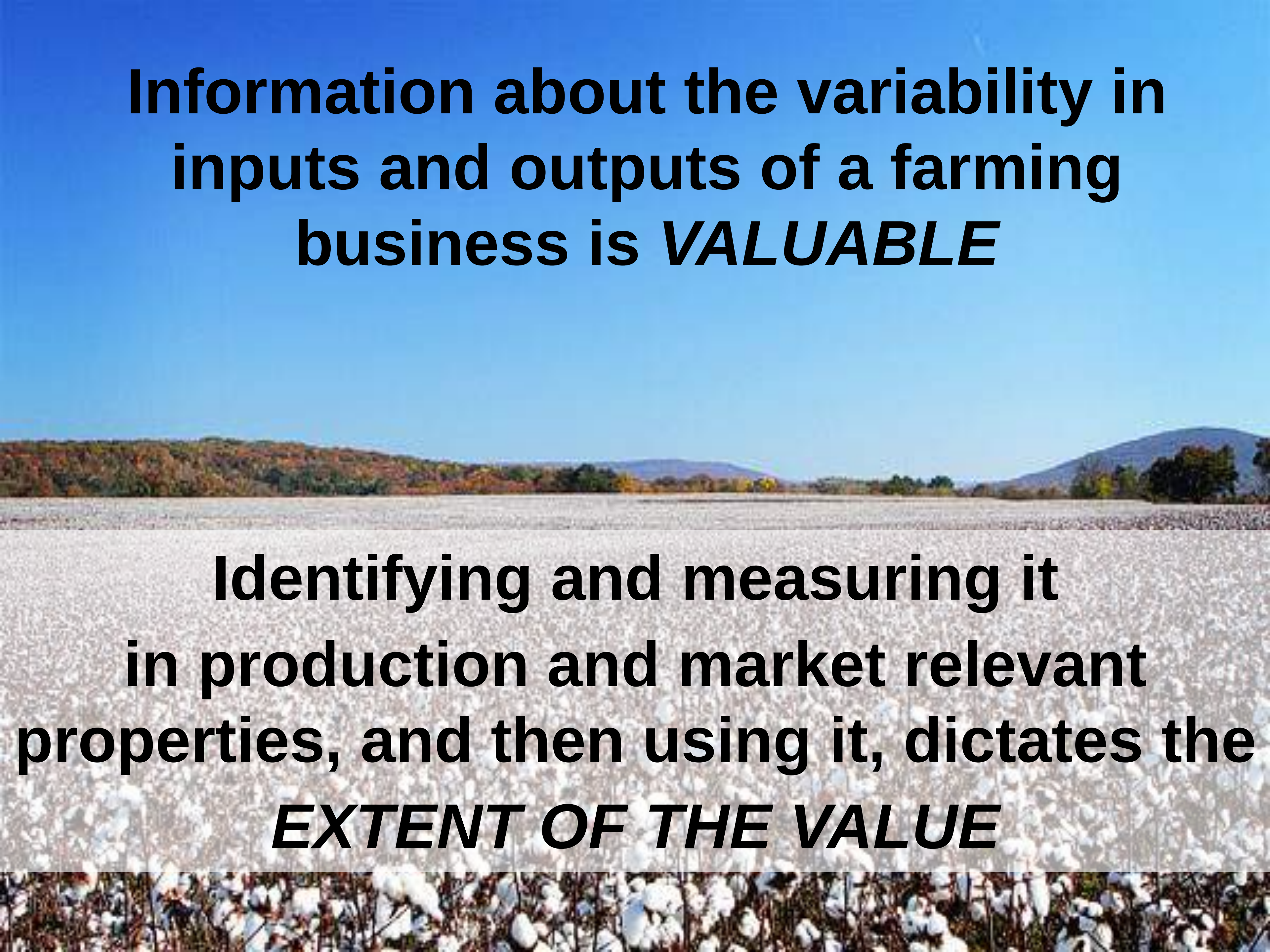
THE UNIVERSITY OF SYDNEY


Information about the variability in inputs and outputs of a farming business is *VALUABLE*
Identifying and measuring it in production and market relevant properties, and then using it, dictates the *EXTENT OF THE VALUE*

Australian Agriculture

- 24.2 million people.
- <4% population employed in agriculture.
- 400M ha for agriculture.
- 8 % used for horticulture and broadacre cropping, but this contributes 56% of agriculture GDP.
- Water is the major limitation to crop growth.
- <1% of agricultural land is irrigated.
- About 14,600 high intensity crop producers (> 50% crops).
- Average high intensity cropping farm size = 1800 ha.

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)

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

Precision Livestock Management (PLM)

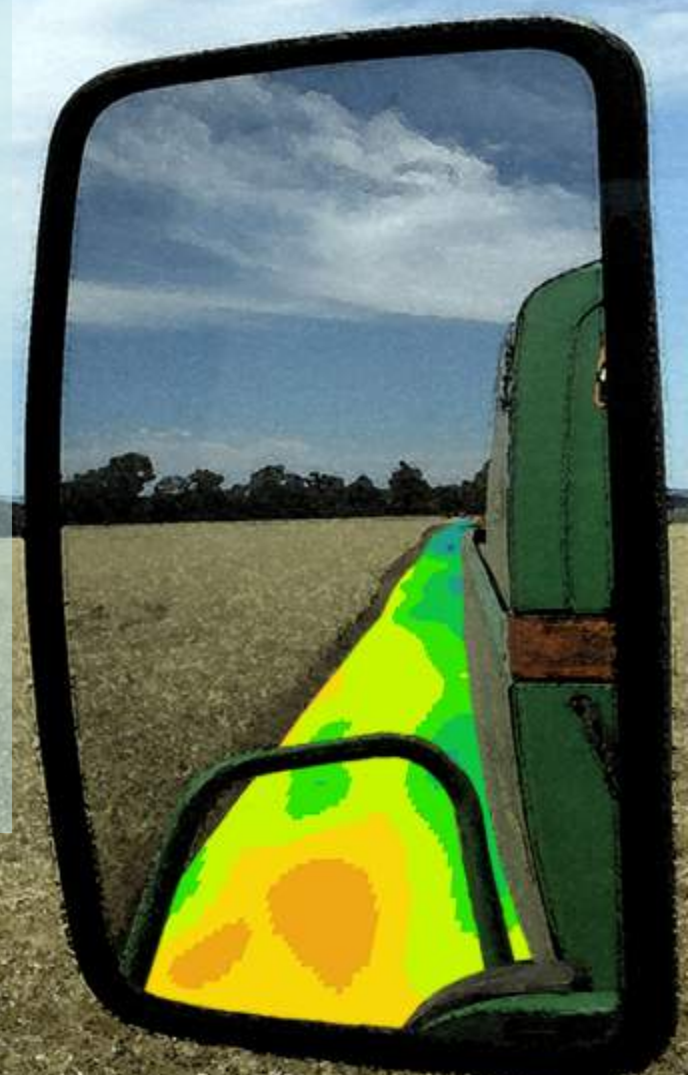
PLM is a form of PA that employs enhanced measurement, monitoring and controlling of the production/reproduction, health, welfare and movement of animals along with their environment.

Precision Agriculture

- **In practice it creates the opportunity to increase the number of (correct) decisions per farm/field/field area/plant/herd/animal/machine/season/marketing transaction made in the businesses of crop and animal management.**
- **It has always been a logical step in the evolution of agricultural management systems toward increased efficiency of input use, minimised waste and improved product quality, traceability and marketability.**

Precision Agriculture in Australia

Australian producers have generally regarded Precision Agriculture as a means of improving resource-use efficiencies initially, with risk management, environmental impact management and marketing benefits following.



Precision Agriculture in Australia

Courier Mail - Saturday 18th October, 1997

Need steers son back to land

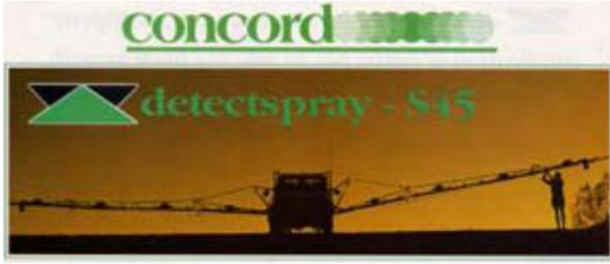
Autosteer vehicle navigation

Beeline Navigator - late1990's
A GPS and inertial guidance system for agricultural machinery

Beeline Navigator, Agsystems Pty Ltd Design Award at 2001 Australian International Design Awards, heavy machinery

Weed detection and spot spraying

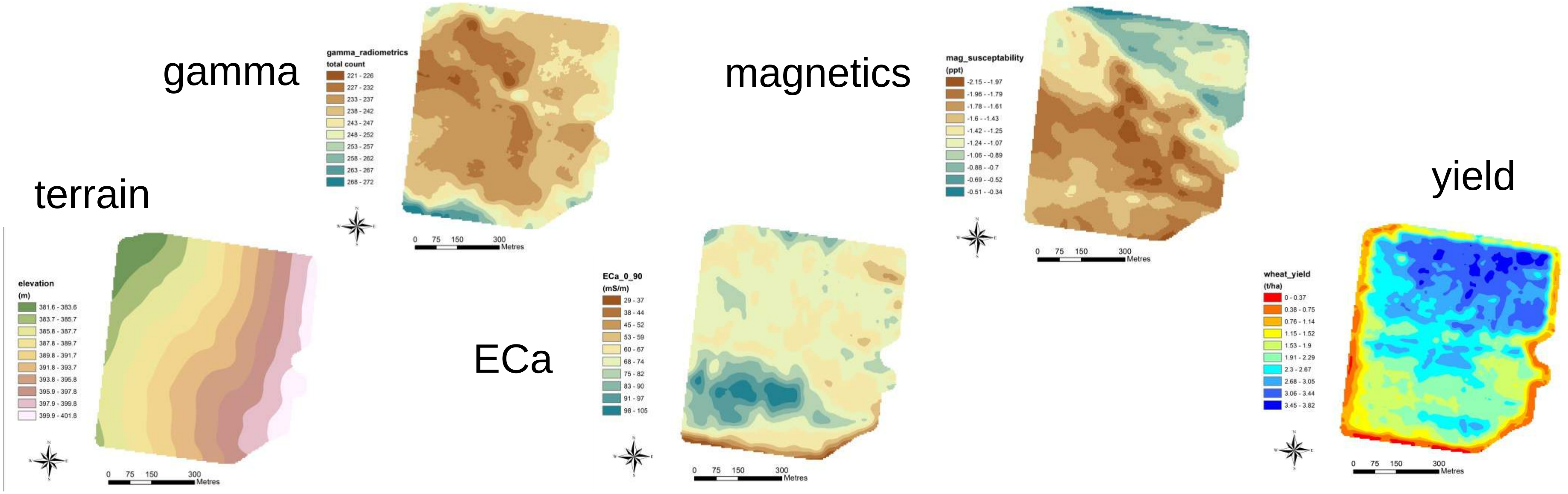
Reflectance activated spot spraying of weeds- commercialised in Canada from research in Tamworth in early 1980's



Felton, W.L. & McCloy, K.R. 1992. Spot spraying. Agricultural Engineering 73: 9-12

Precision Agriculture @ the University of Sydney

Digital data



Precision Agriculture @ the University of Sydney

- Philosophical motivation – the null hypothesis
- Optimised spatial prediction & mapping regimes
- Management class partitioning
- Designing and analysing within-field experiments & directed soil and plant point sampling
- Agronomic diagnosis and variable-rate input management


New data-driven management strategies

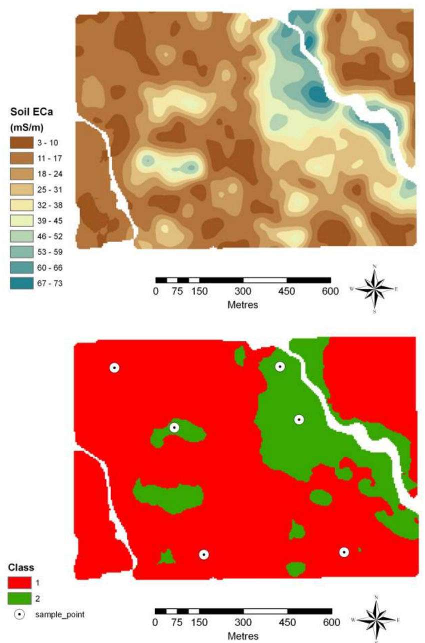
Controlling nutrient input

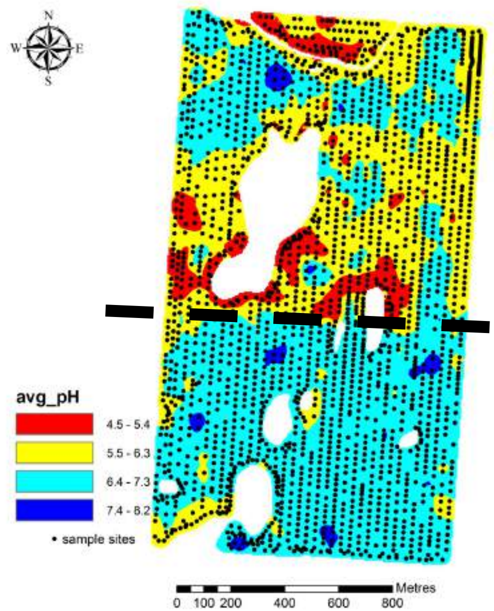
- Readjustment of yield goals, either uniform or spatially variable.
- Nutrient replacement based on a sound understanding of spatial variability in field and environmental resources and off-take.
- Optimal application based on spatial variation in measured response to inputs.

New data-driven management strategies

Controlling ameliorant input

- **Variable-rate lime and gypsum application based on Soil ECa or pH mapping.**





Protein monitoring instruments

Data Density Comparisons

Yield Sensor Data

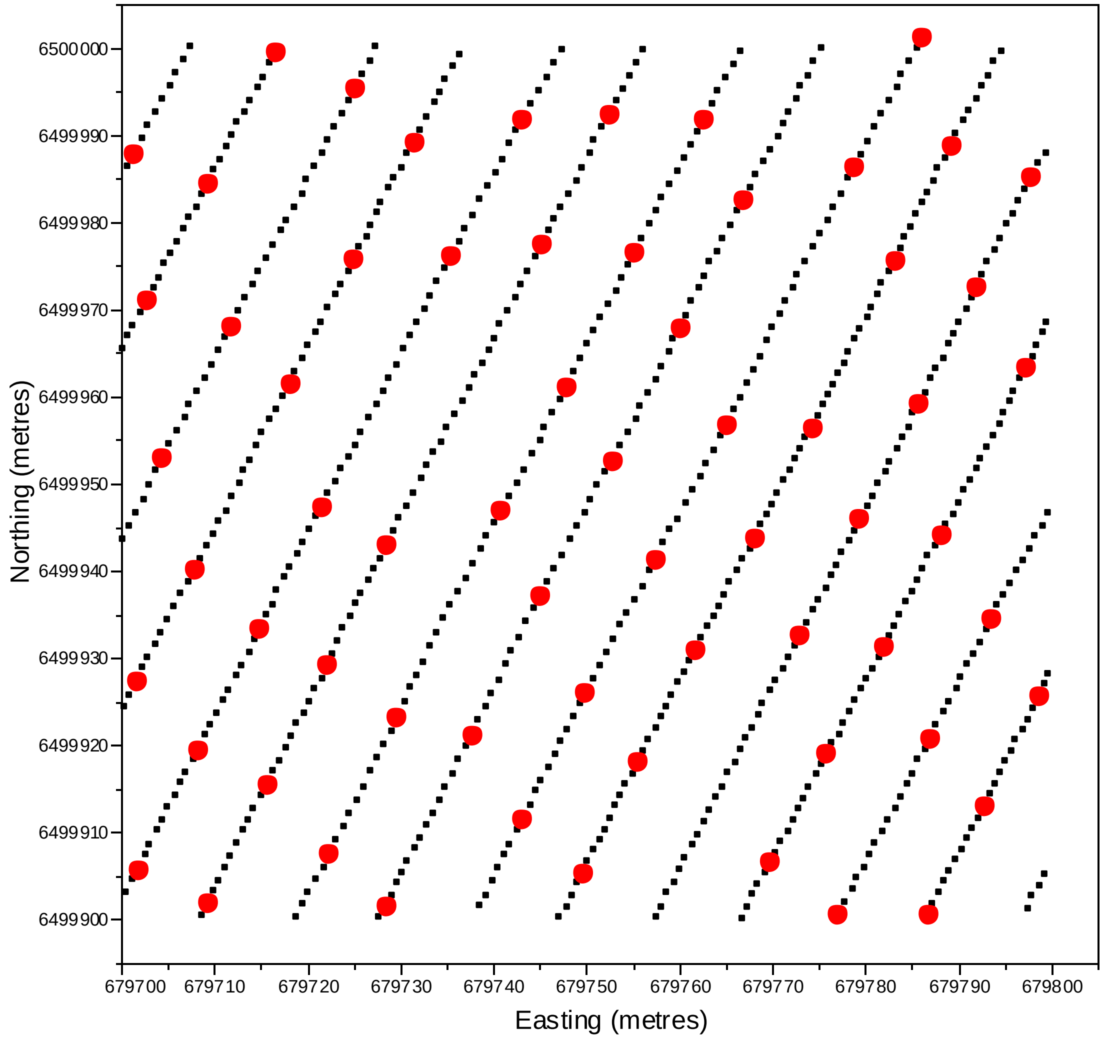
725/ha

(1 second cycle)

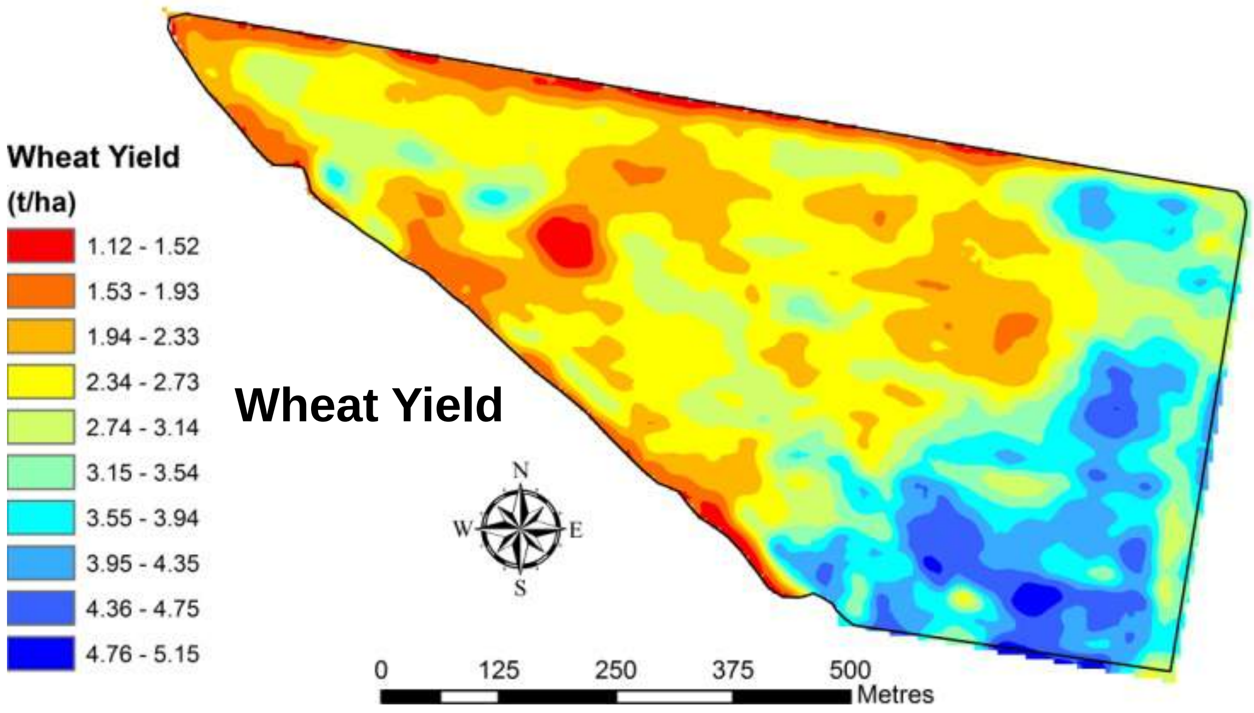
Protein Sensor Data

65/ha

(~12 second cycle)

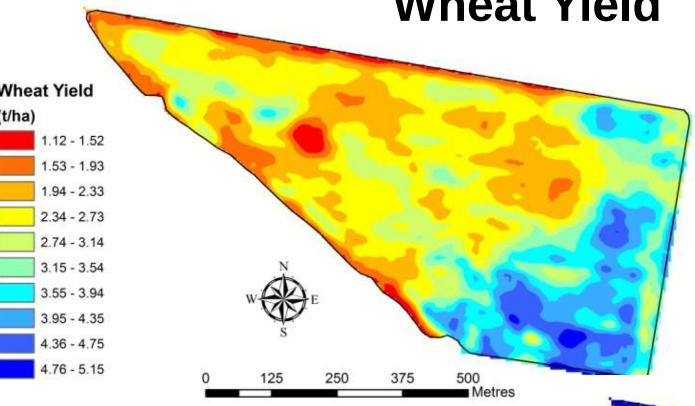


Protein monitoring instruments

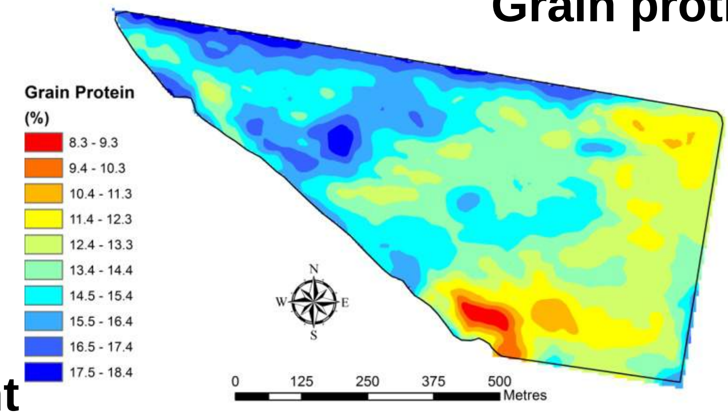


Calculating site-specific gross margins

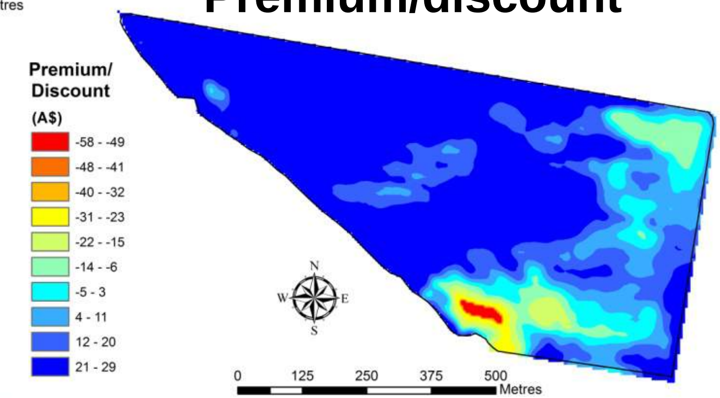
Wheat Yield



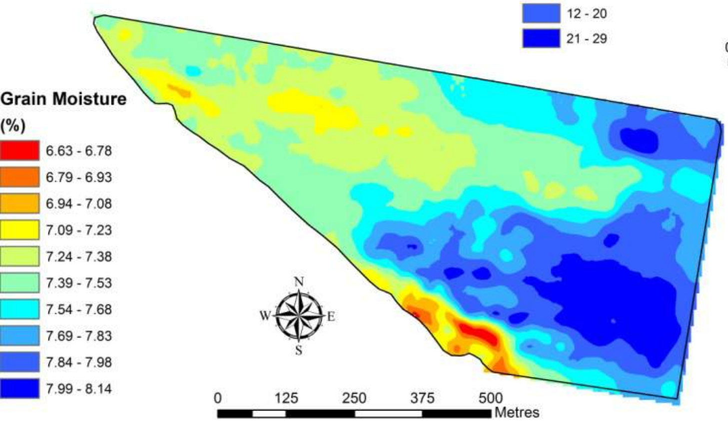
Grain protien



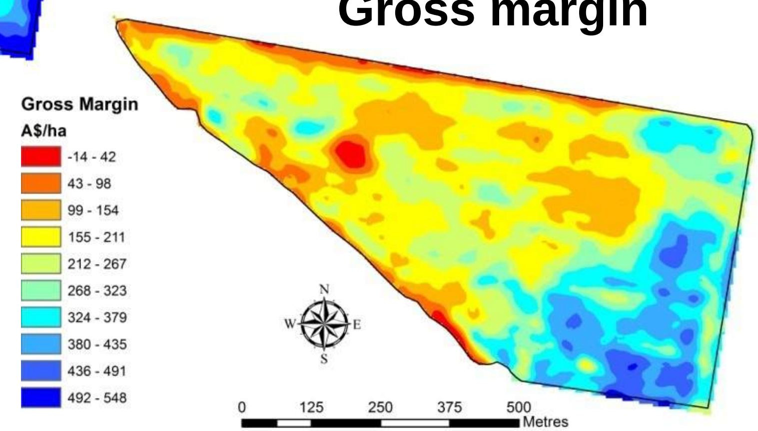
Premium/discount



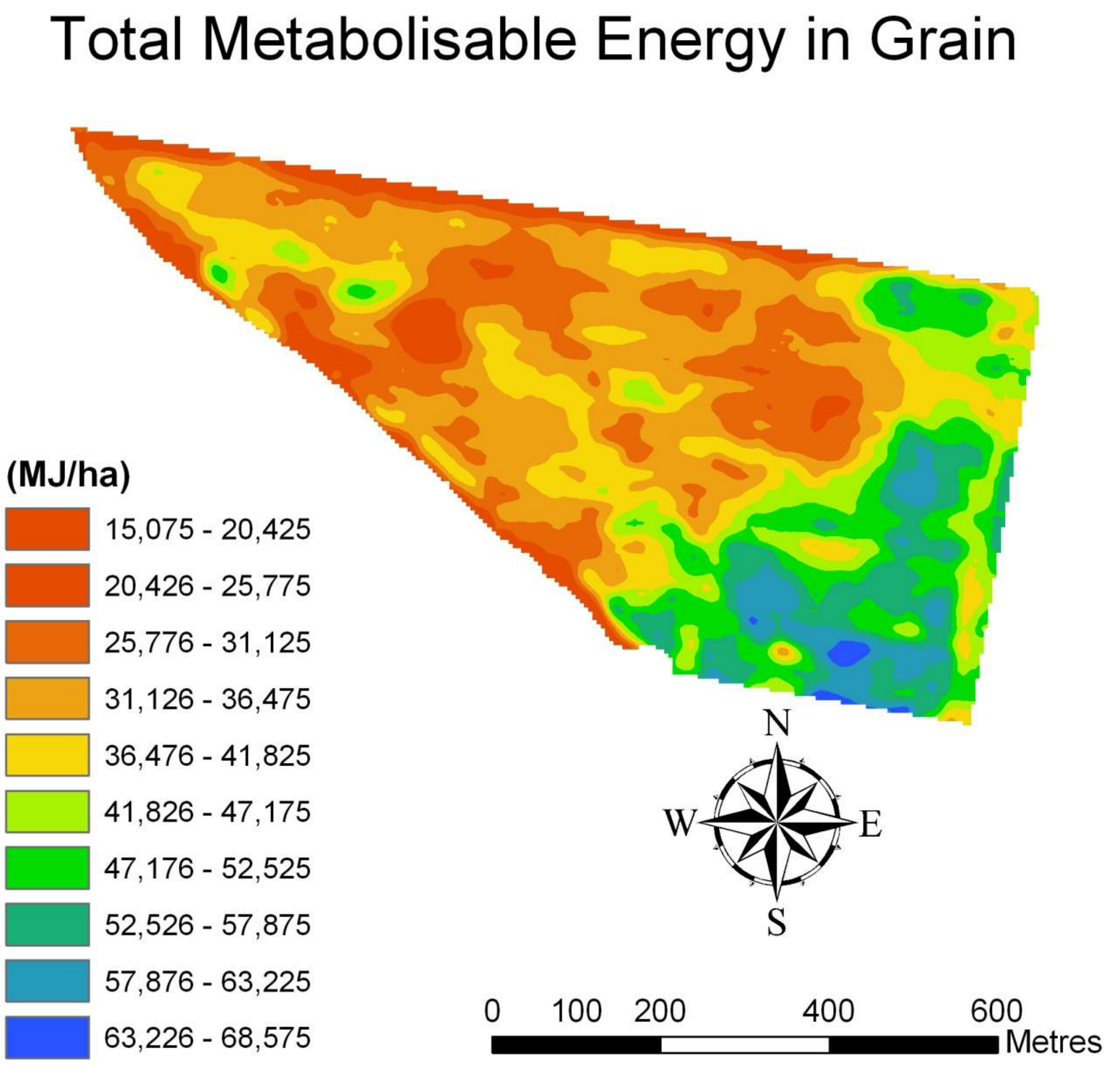
Grain moisture



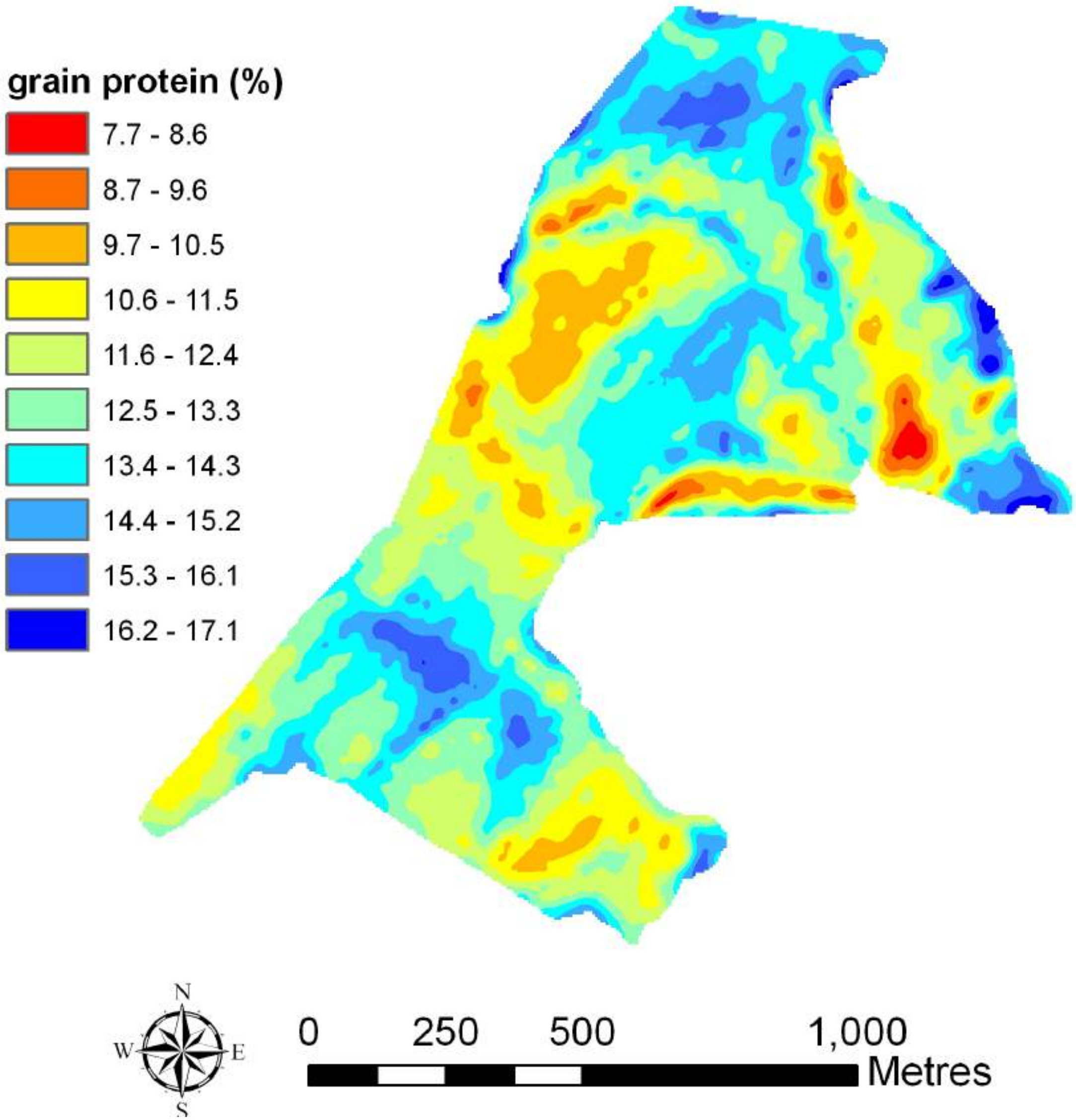
Gross margin



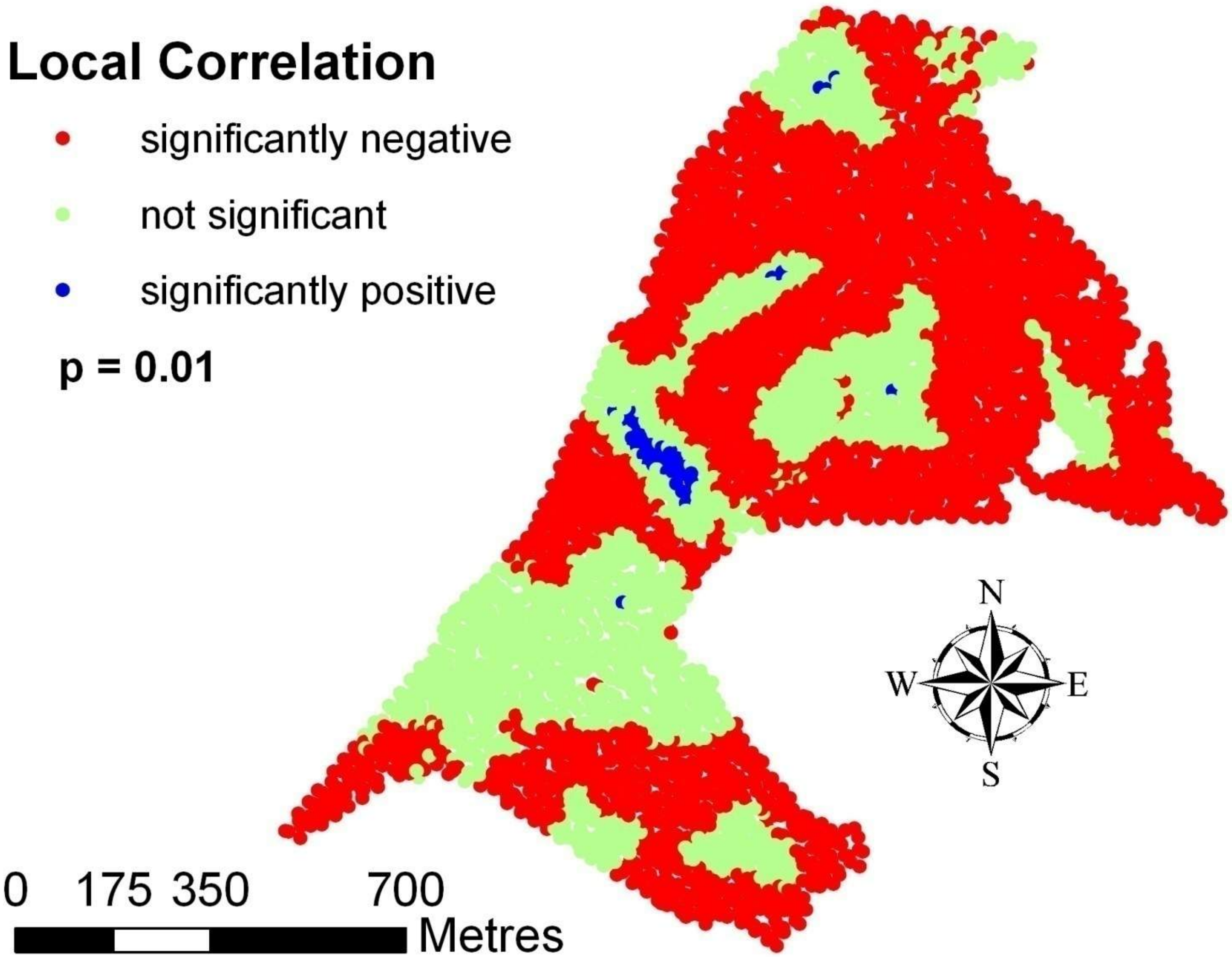
Calculating TME

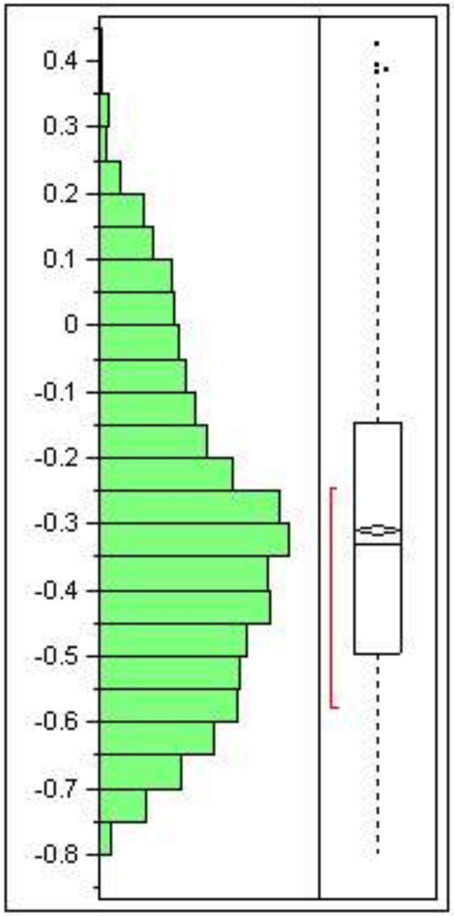


Protein monitoring instruments



Protein monitoring instruments





Distribution of correlation coefficients

Proximal crop reflectance sensors

NTech® Industries, Inc.
A TRIMBLE COMPANY

Holland SCIENTIFIC

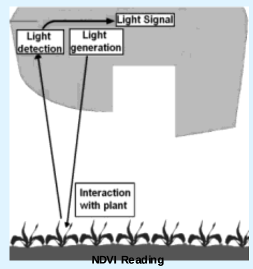
YARA

TOPCON
Precision Agriculture

Improving the in-season prediction of yield for use in N application algorithms

In-Season

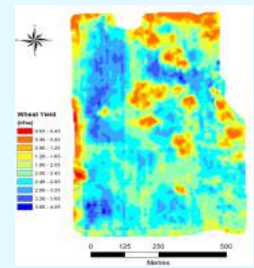
Crop Reflectance



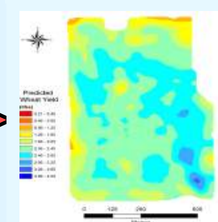
YP0 = Yield without extra fertiliser

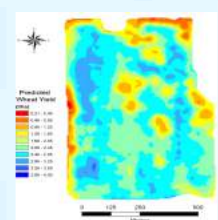
$$YP0 = 1800 \times e^{\frac{NDVI \times 85}{DFP}}$$

Post-Season



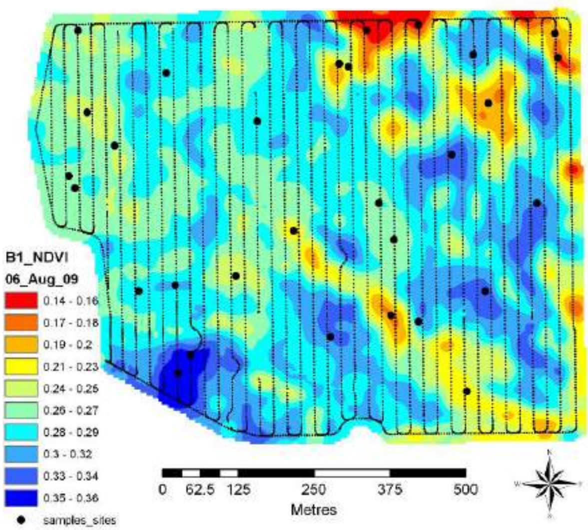
Standard method



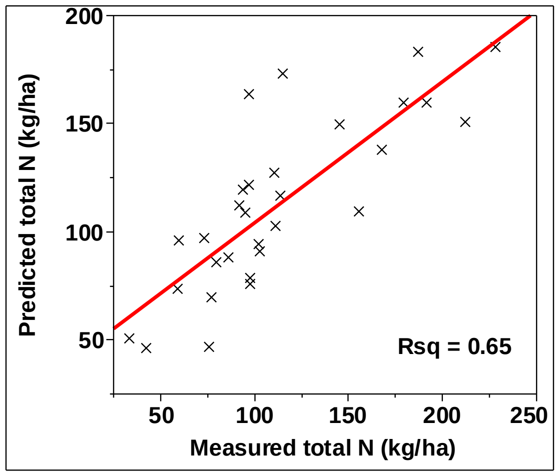


Calculating whole field N requirements

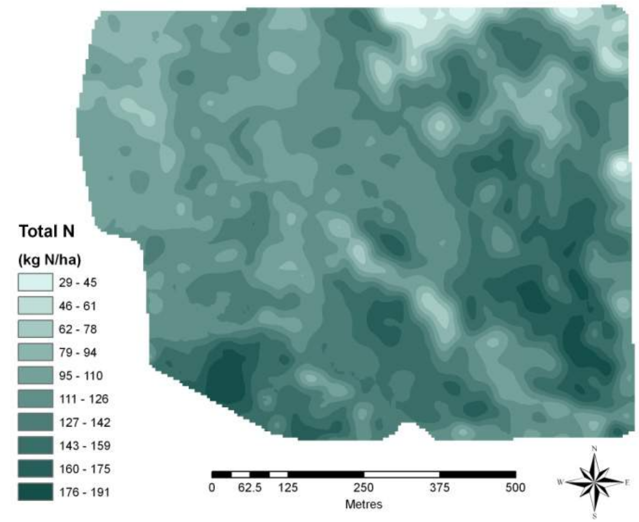
Reflectance



Calibration with crop N



Total crop N



N uptake required for a 4 t/ha wheat crop:

4 x 12 x 1.75 = 84 kg N/ha

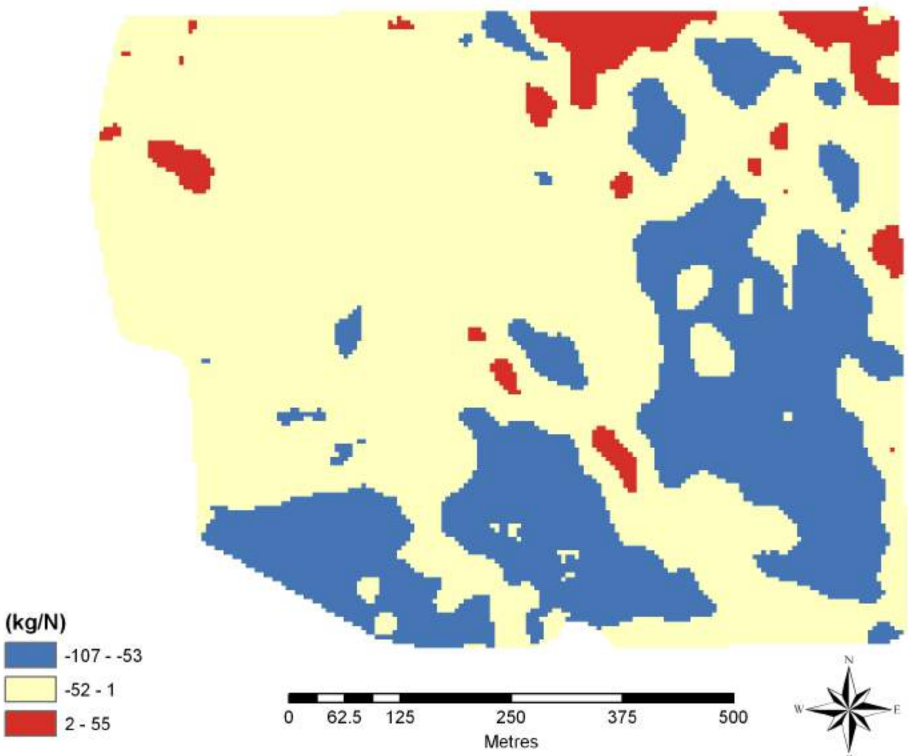
yield goal

protein goal

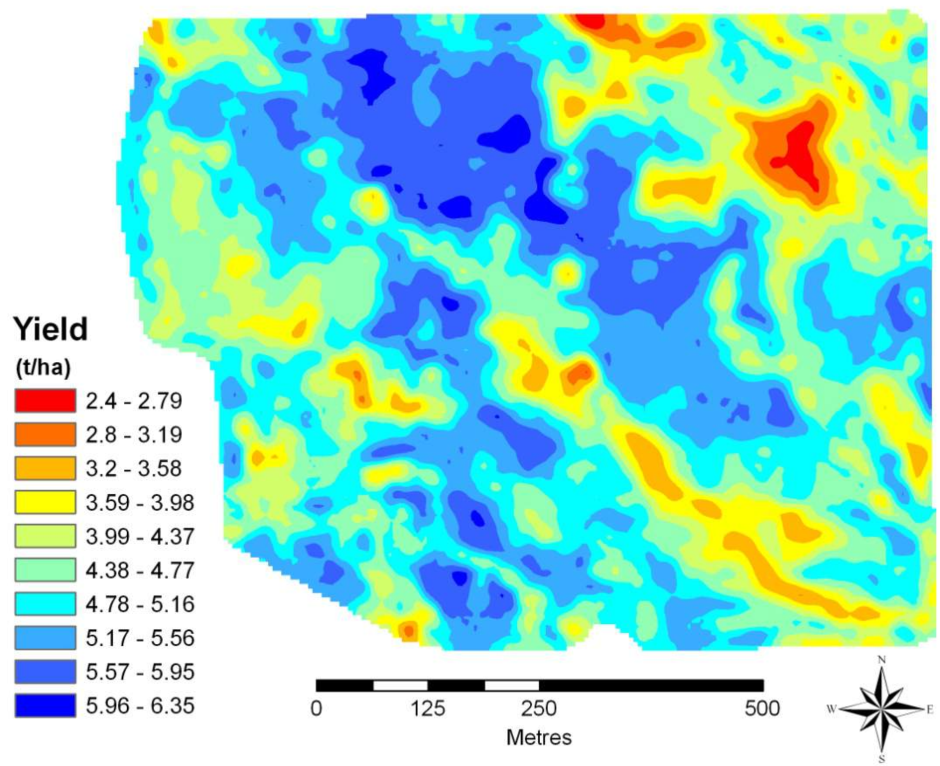
factor related to the % of N in protein

Calculating whole field N requirements

N required in crop for yield goal



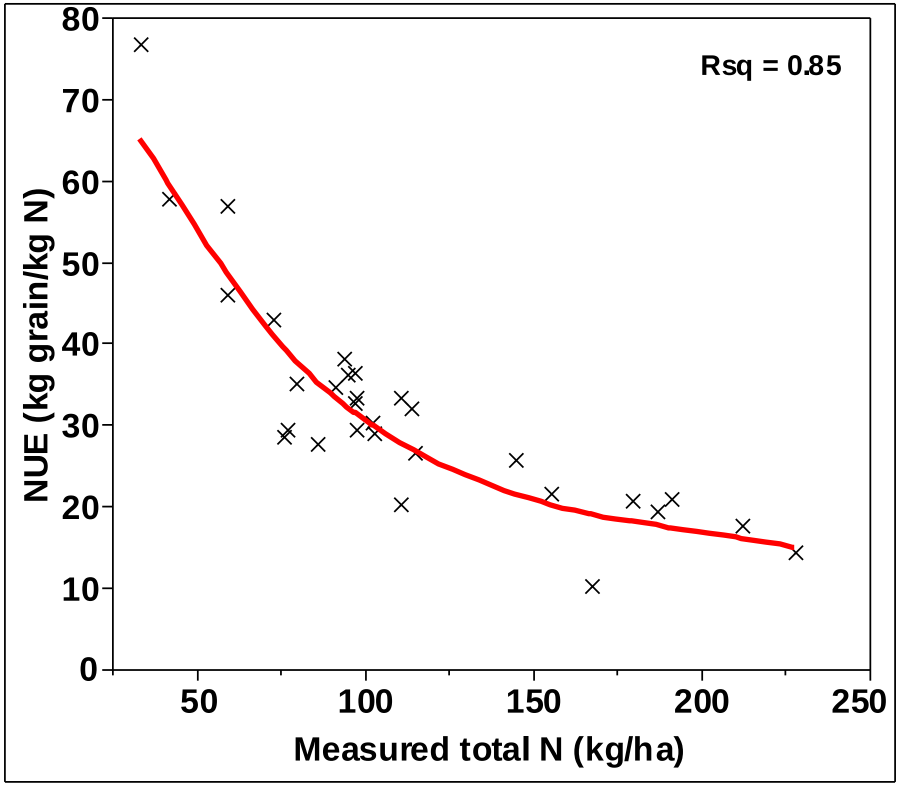
Crop yield



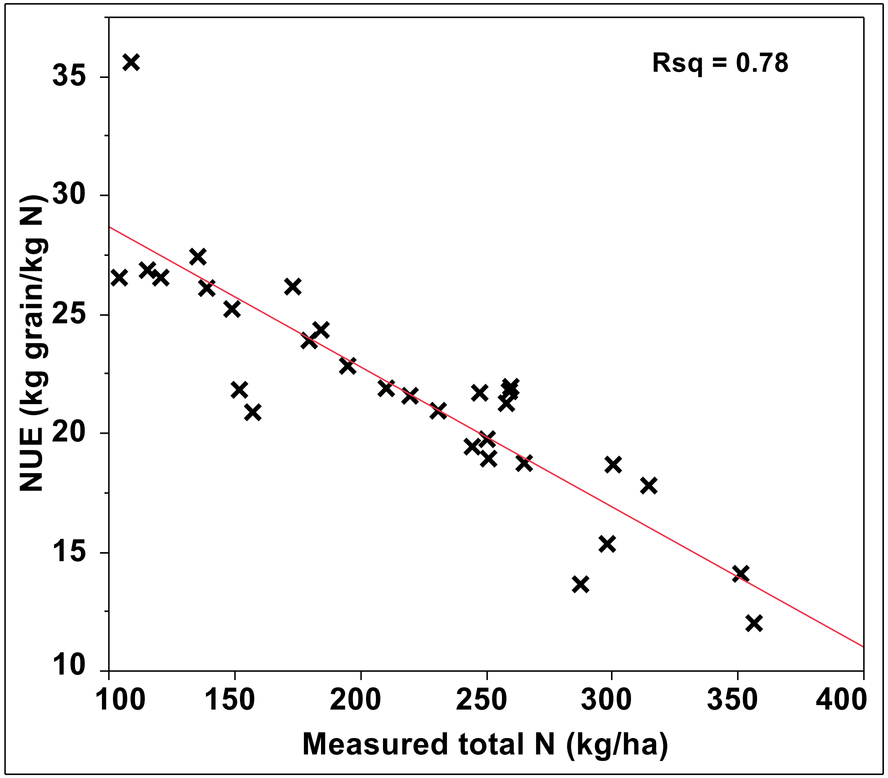
Except for the sandhills, the rest of the paddock easily achieved the yield goal

Nitrogen use efficiency

Kg of grain / kg of N in crop vegetative matter



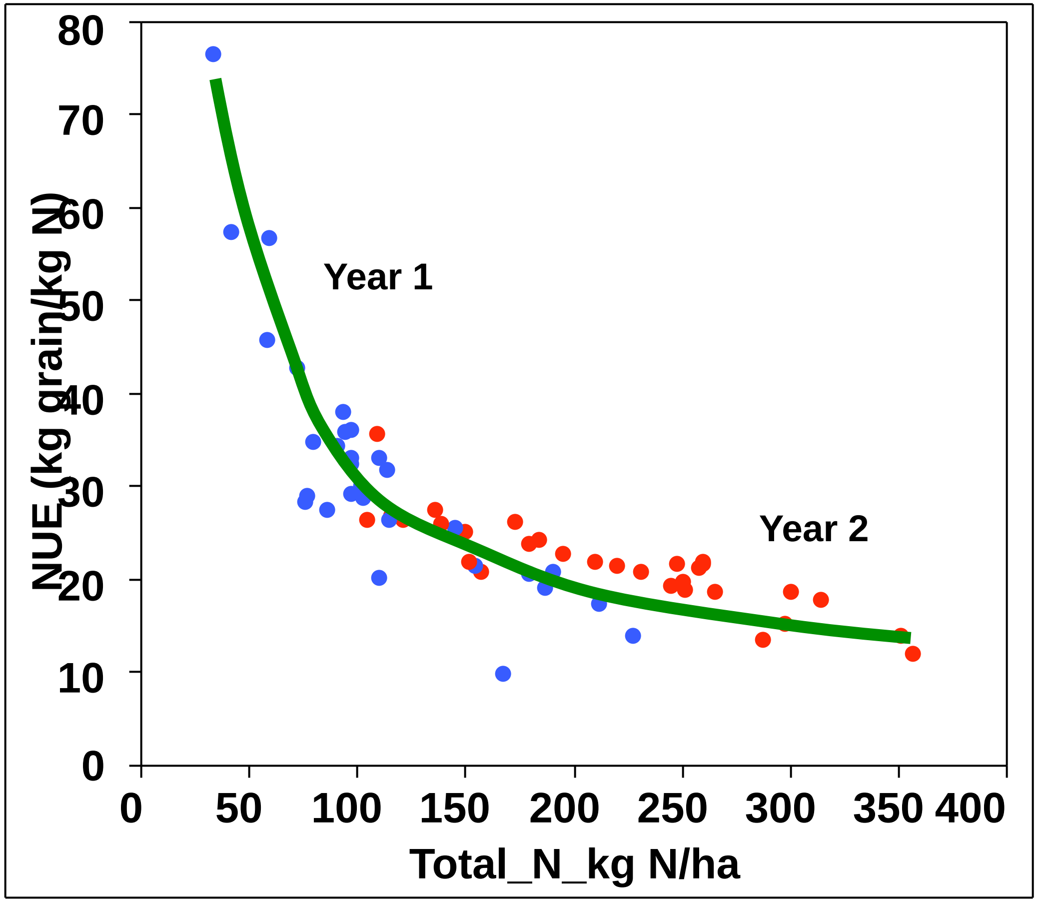
Year 1



Year 2

Nitrogen use efficiency

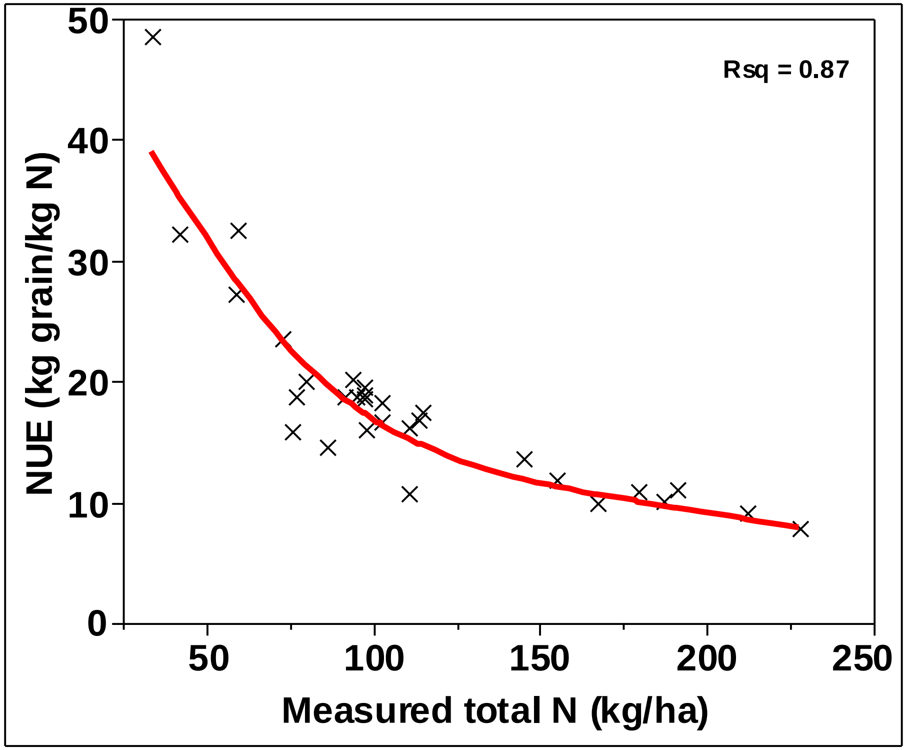
Kg of grain / kg of N in crop vegetative matter



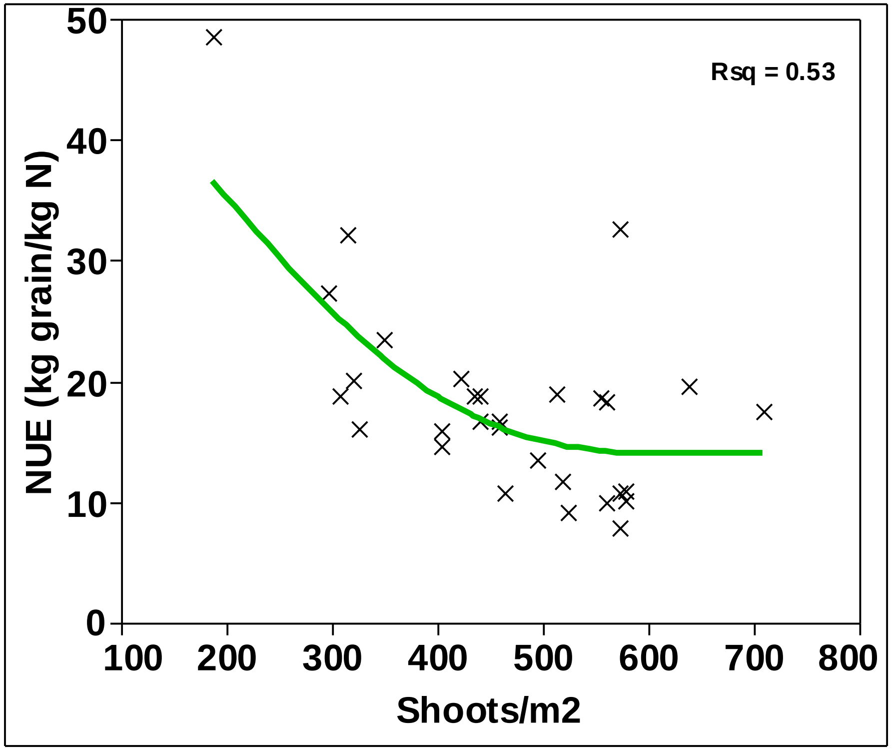
The conversion rate of crop N into crop yield (NUE) decreases as the total amount of N taken up by the crop increases.

Nitrogen use efficiency

NUE of N in crop relative to total N uptake



NUE of N in crop relative shoots/m2



NUE plateaus at 550 - 600 shoots/m^2 and 14kg grain for every kg of N in the crop. Hitting 550 shoots/m^2 should optimize the yield/N ratio and confirms much of the recent canopy management advice

Digital agri-food and fibre systems - goals

- Increased efficiency, profitability and sustainability with respect to the use of inputs such as labour, nutrients, water, energy, and agrochemicals.
- Greater traceability and marketability of individual farm commodities and food and fibre products.
- Greater adaptability to changes in the environment and in consumer/market requirements (e.g. quality, nutrition, size).
- Ability to deliver the quantity and quality of commodities and products that meet the challenges of maintaining soil, food and nutrition security.

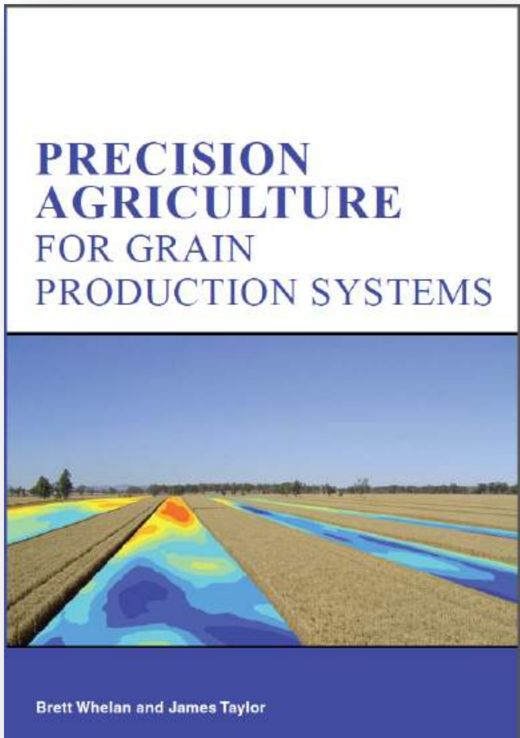
Digital agri-food and fibre systems - goals

Meeting the goals

- **These systems will need to identify, gather and use relevant digital data in a more diagnostic way to optimise management and outcomes across all aspects of the breeding and selection (crops and animals), production, marketing, distribution, retail and consumption sectors.**

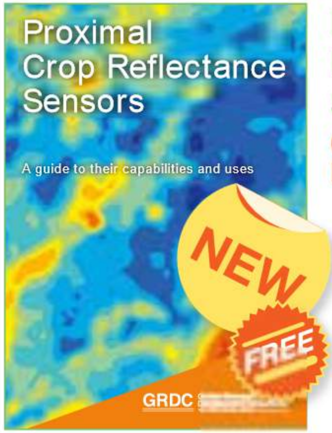
A great global challenge for bright, considerate minds

Education tools for PA



Textbook

Training materials



PROXIMAL CROP REFLECTANCE SENSORS
ORDER CODE: GRDC982
PRICE: FREE plus p&h

ADVANCED FIELD-SCALE EXPERIMENTATION FOR GRAIN GROWERS
ORDER CODE: GRDC981
PRICE: FREE plus p&h

Research to practice

New stream for agricultural education

- Knowledge of basic biology of animals, plants, pests and diseases
- Knowledge of farming systems and critical decision points
- Knowledge of the design and application of engineering solutions, sensing technologies, data capture platforms, and data integration
- Knowledge of supply chain concepts in food and fibre industries
- Ability to analyse/integrate 'big data' to devise business-optimal management plans in food and fibre industries

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Site-Specific Crop management

Financial Benefits

Vehicle Navigation Systems:
savings in input costs
(chemical, fuel, labour) ~5 – 15%

SpotSpray Technology:
Chemical savings ~A$12/ha – A$30/ha

VRA Application of Fertilisers:
Improvements in gross margin -
~A$5/ha – A$65/ha in paddock-scale experiments
~A$12/ha – A$42/ha for whole-farm rotations

Production Decision Support

- A tool that contains the capability of autonomously adapting decision functions and providing the farmer with alternative scenarios as input data changes across space and/or time.
- Involves the novel integration of relevant data from diverse domains, sources and scales to improve decision management at the sub-paddock level, within bounds of optimising the whole business profitability, and sustainability.
- Water, nitrogen and canopy management focus

Digital Agri-Food and Fibre Systems - Goals

Meeting the Goals

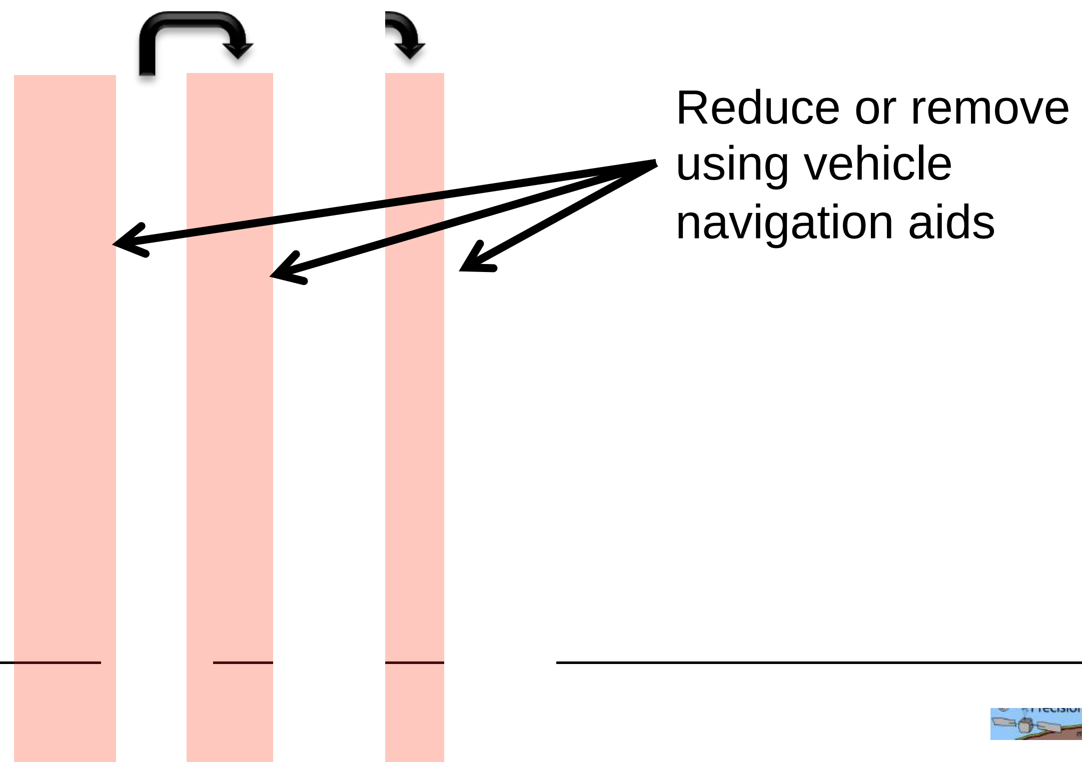
- These systems will need to identify, gather and use relevant digital data in a more diagnostic way to optimise management and outcomes across all aspects of the breeding and selection (crops and animals), production, marketing, distribution, retail and consumption sectors.

GPS-based vehicle navigation systems

Guidance and autosteer

Application overlap using conventional marking tools can be anywhere from 0.2 metre to 0.5 metres *i.e.*

- 3% to 6% on a 9 metre wide sowing implement; and
- 1% to 2% on a 27 metre wide spraying implement.

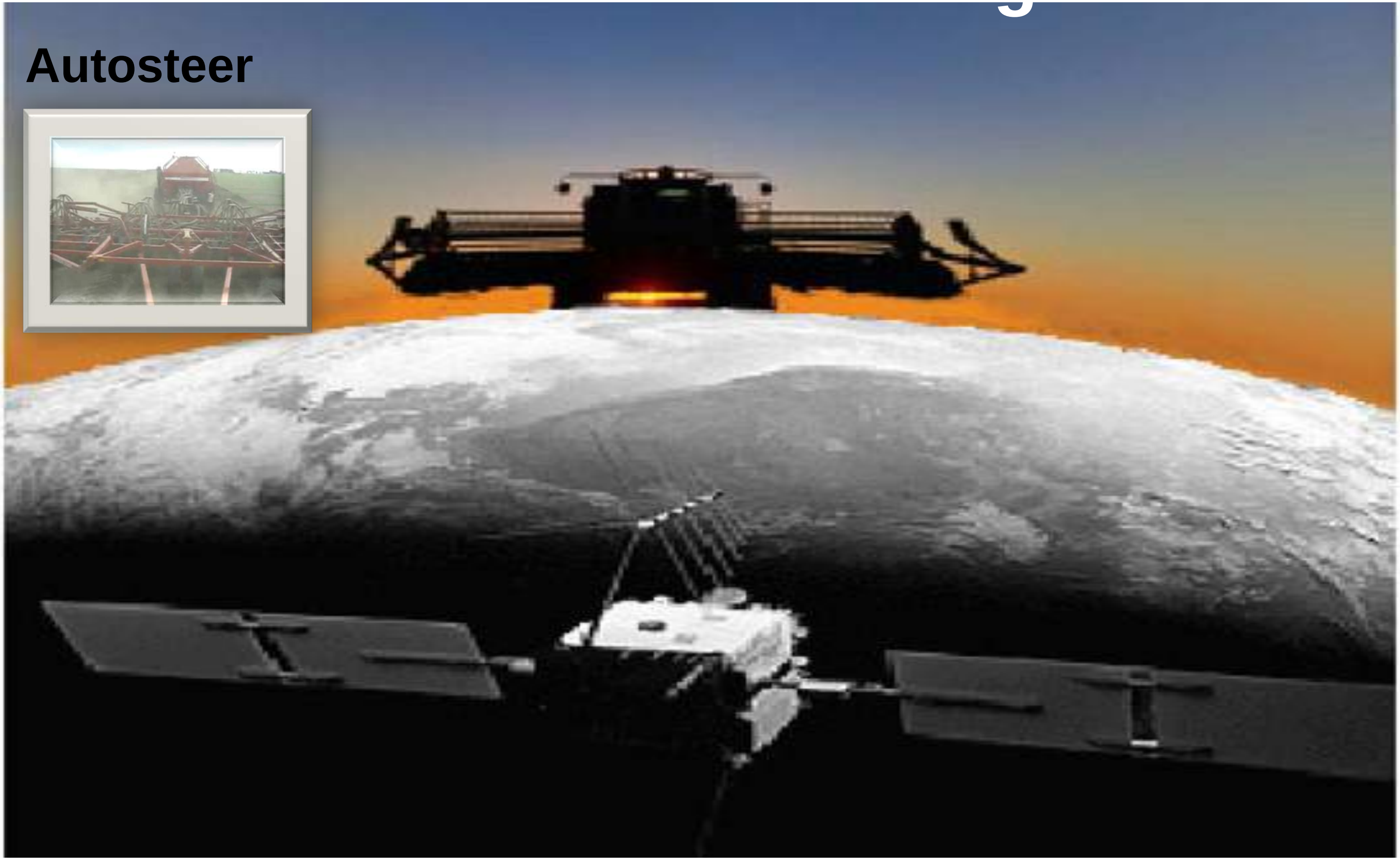


New agricultural education

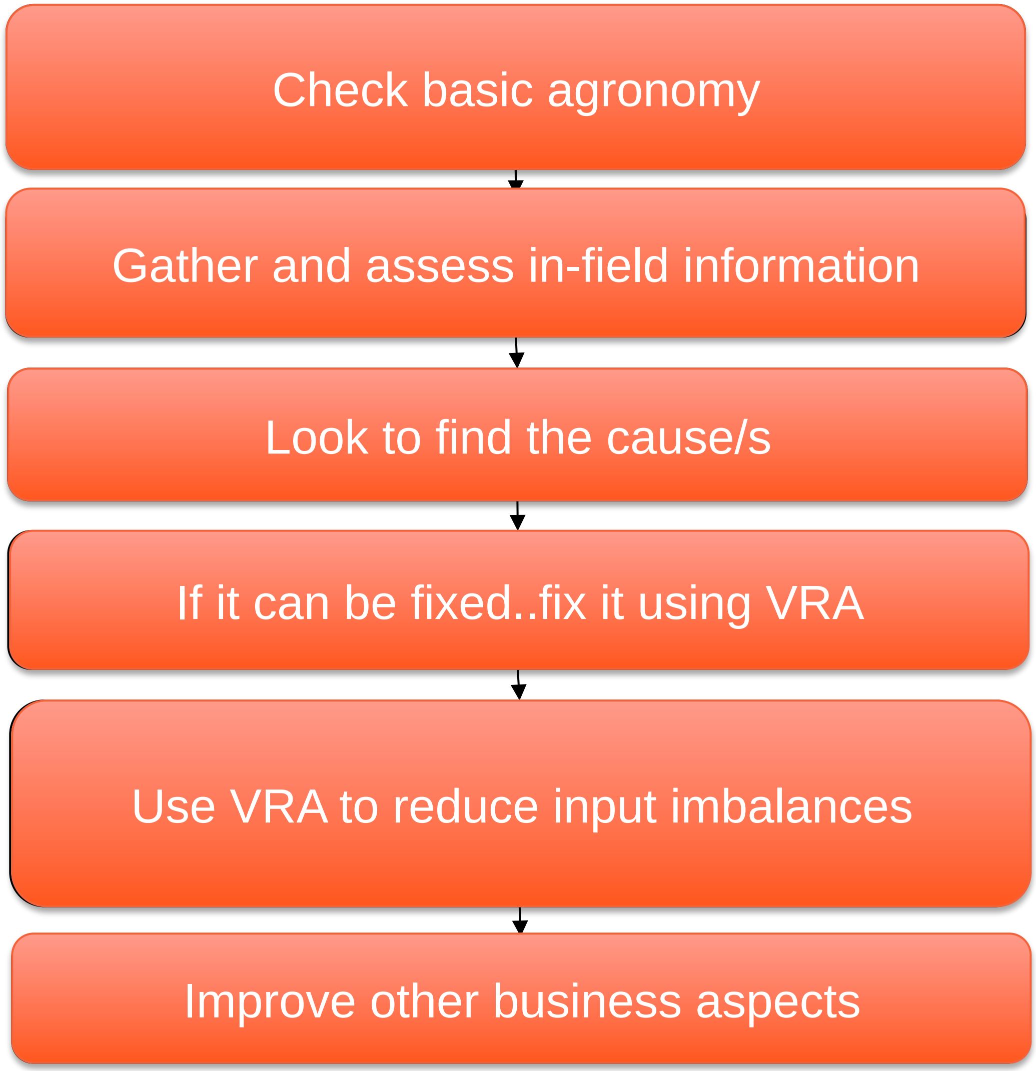
Educational requirements

- **Knowledge of basic biology of animals, plants, pests and diseases**
- **Knowledge of farming systems and critical decision points**
- **Knowledge of supply chain concepts in food and fibre industries**
- **Knowledge of the design and application of engineering solutions, sensing technologies, big data capture platforms, and data integration**
- **Ability to analyse big data to devise optimal response plans in food and fibre industries**

GPS-based vehicle navigation systems



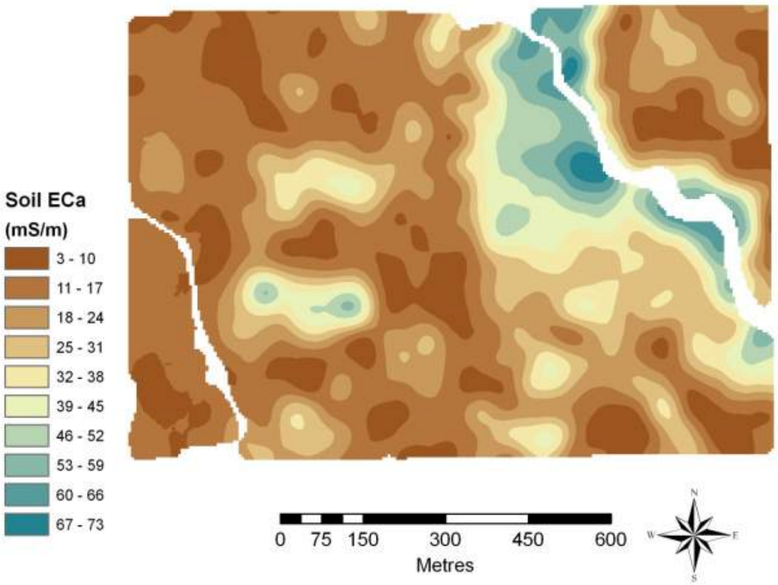
Strategy for incorporating SSCM

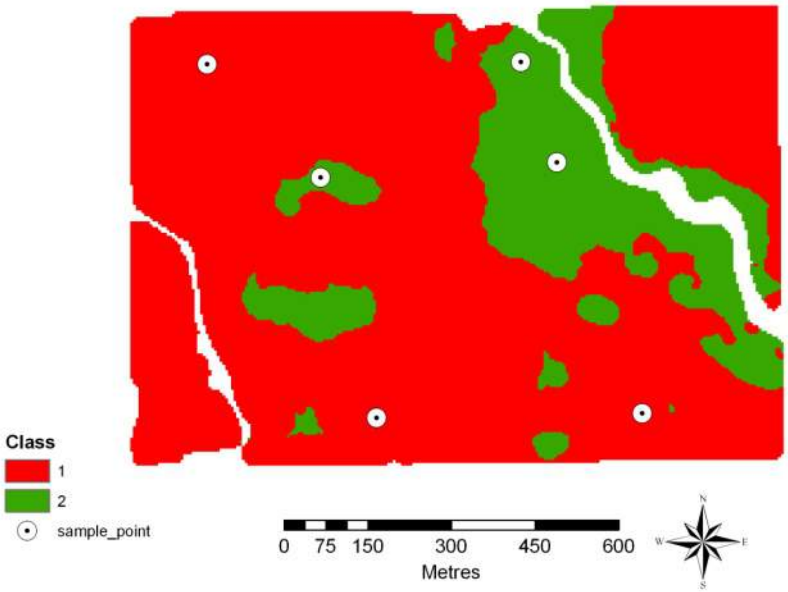


Strategy for incorporating SSCM

1. Check basic agronomy
2. Gather and assess in-field information
3. Look to find the cause/s
4. If it can be fixed..fix it using VRA
5. Use VRA to reduce input imbalances
6. Improve other business aspects

Variable-rate lime application



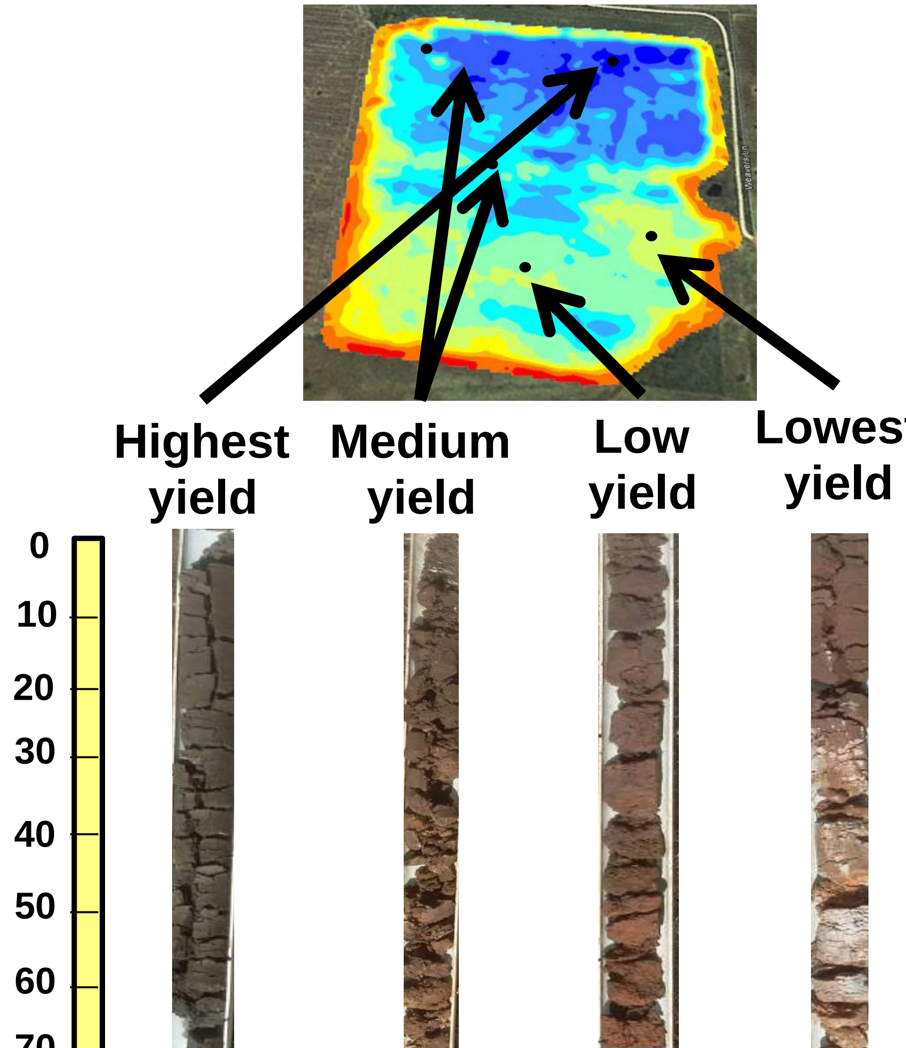


Field portion	Size (ha)	Topsoil pH	Lime recommended (t/ha)	Cost @ $50/t spread ($/area)	Cost of whole field treatment at pH 4.8
Class 1	79	5.7	monitor	0	3710
Class 2	16	4.8	1.3	1040	1040
Total	95			1040	4750

78% saving

Soil pH results, lime recommendations and costs for class-specific or whole-field treatment

Digital soil surveys and diagnostics



Data-Driven Decisions

– Merge (large) data streams from diverse sources and scales with adaptable crop and environmental models that feed information into key decisions.

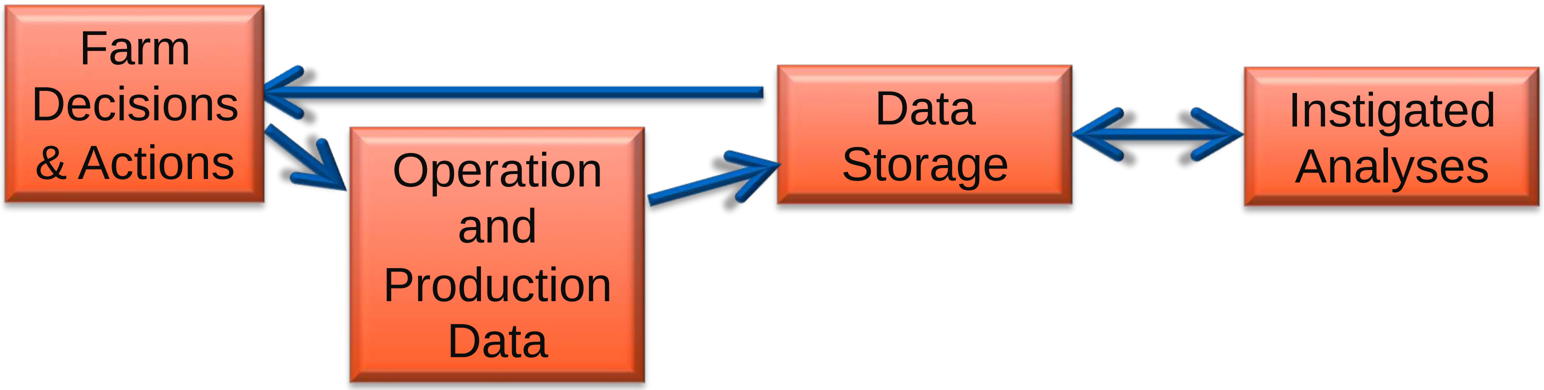
<u>Components include:</u>

– **Data generation and capture (historic and real-time).** These may include yield maps, aerial/proximal sensing (vigour, disease, pest), soil, environment, economics/markets.
– **Data warehouses.** These may eventually store data in the cloud using wireless data transfer.
– **Prescription agriculture.** Alternative options for crop management, variable-rate application and farm logistics based on probabilistic assessment of causal relationships.

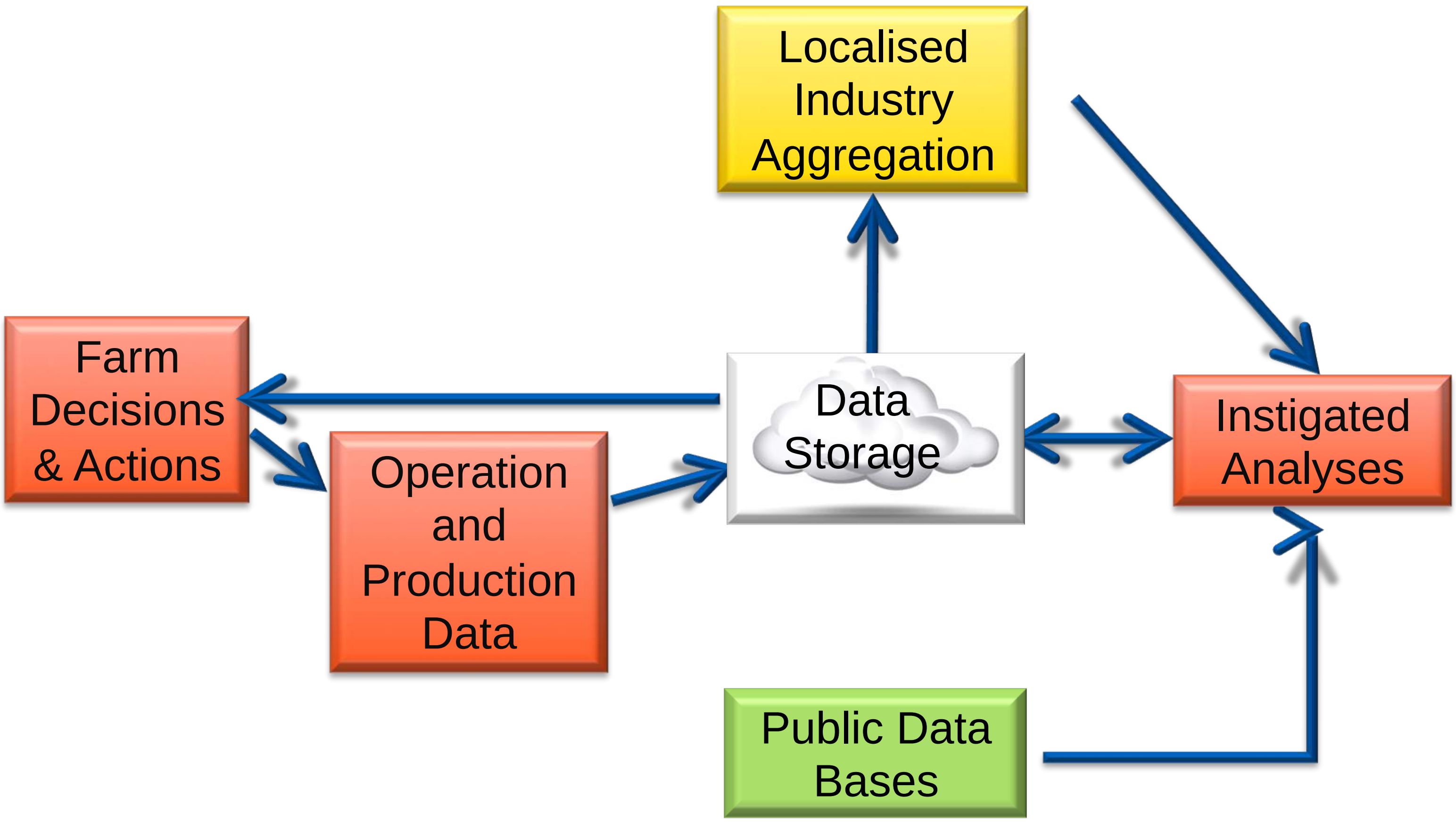
Data-Driven Decisions

- The practical goal is to increase the number of (correct) decisions per hectare/per season made in the business of crop management.
- The potential financial benefits from using data to better managing inputs to match variability in operations varies with each field & farming business, but the potential improvements in gross margin ($/ha) are significant.

SSCM decision support



SSCM decision support



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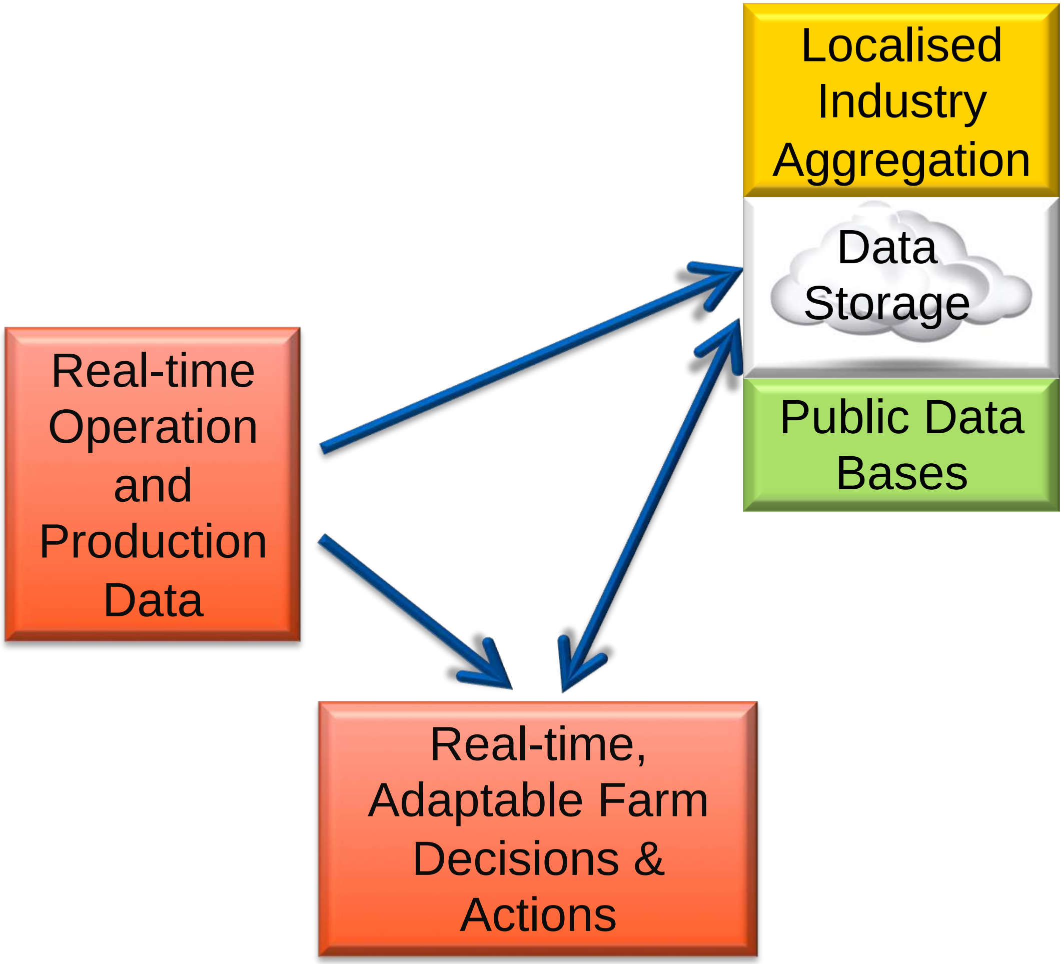

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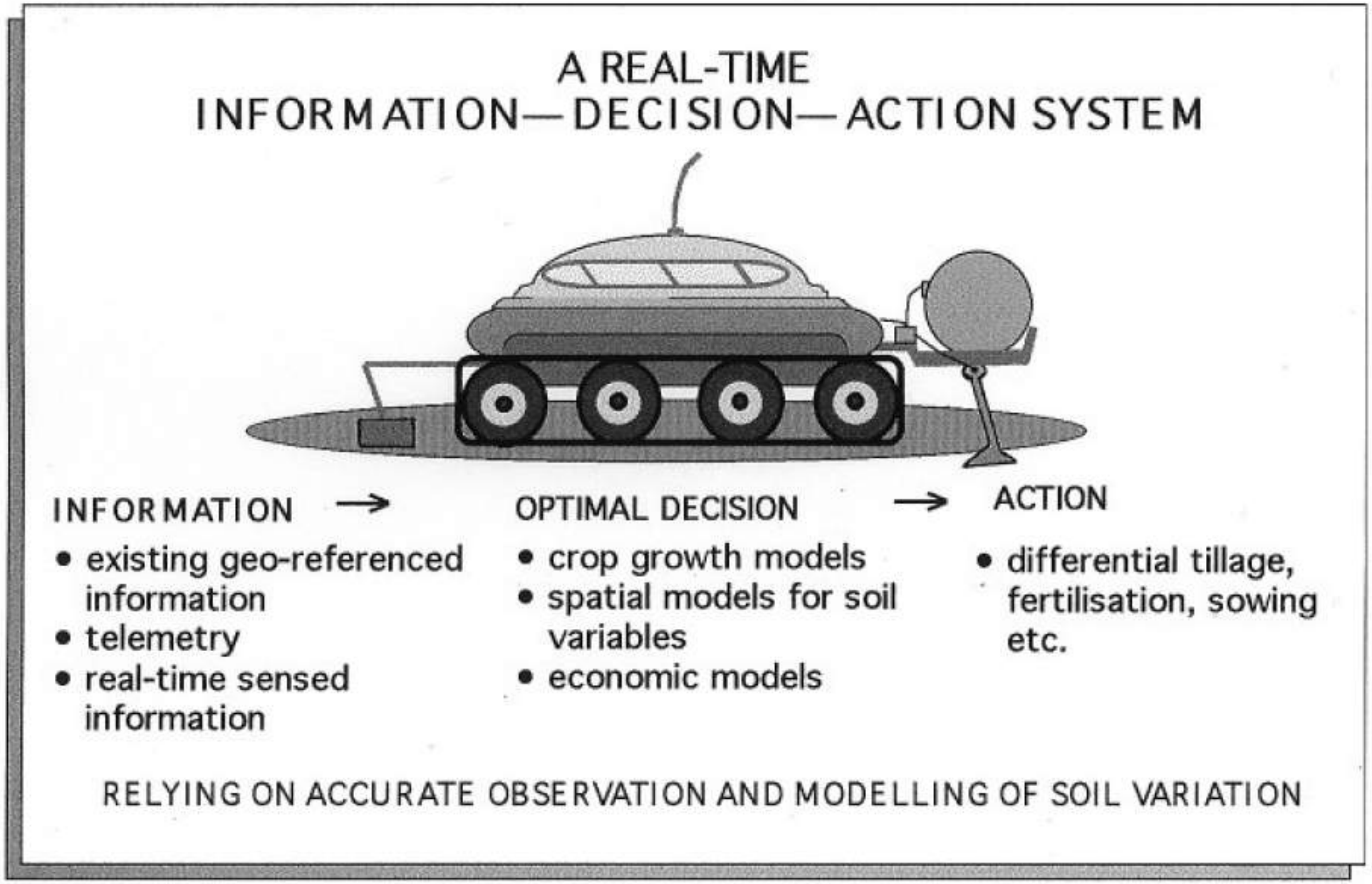
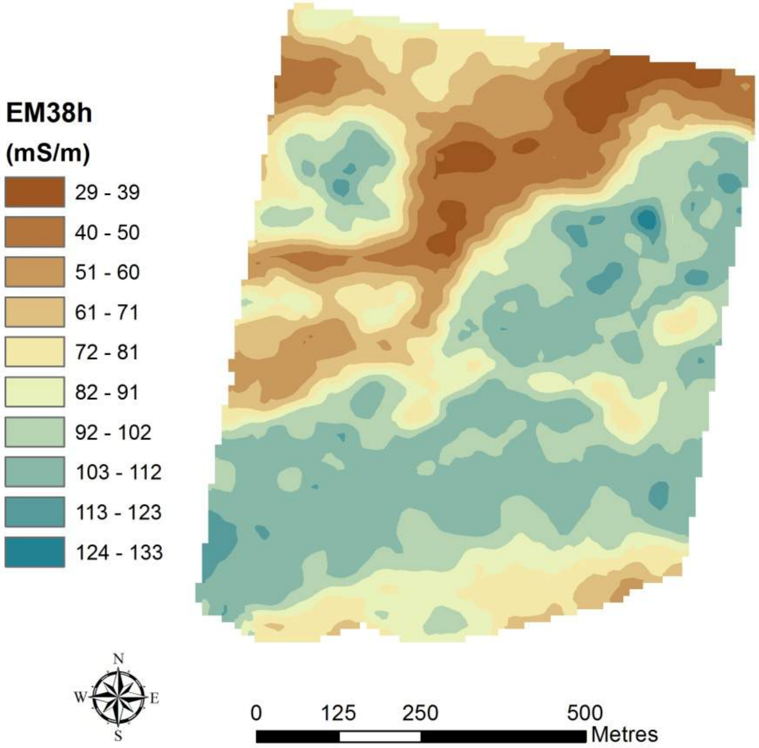
A Vision

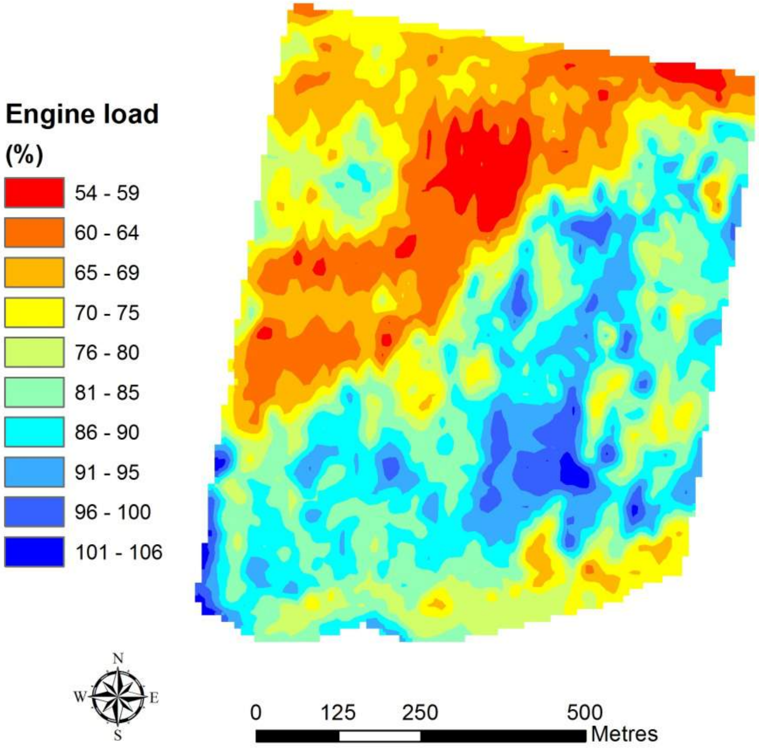


McBratney, A.B. & Whelan, B.M. (1995) *The Potential for Site-Specific Management of Cotton Farming Systems*. CRC for Sustainable Cotton Production, 46p.

Vehicle engine load during sowing

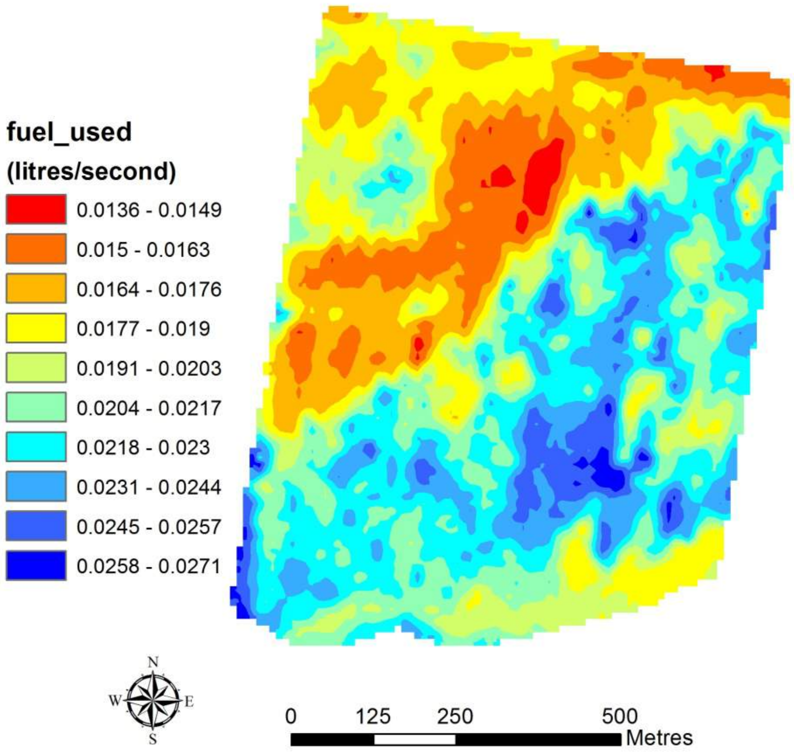


Soil ECa measured using EM38h



Engine load (% of total power rating)

Data supplied by Rupert McLaren, McLaren Farms ‘Glenmore’, Barmedman, NSW



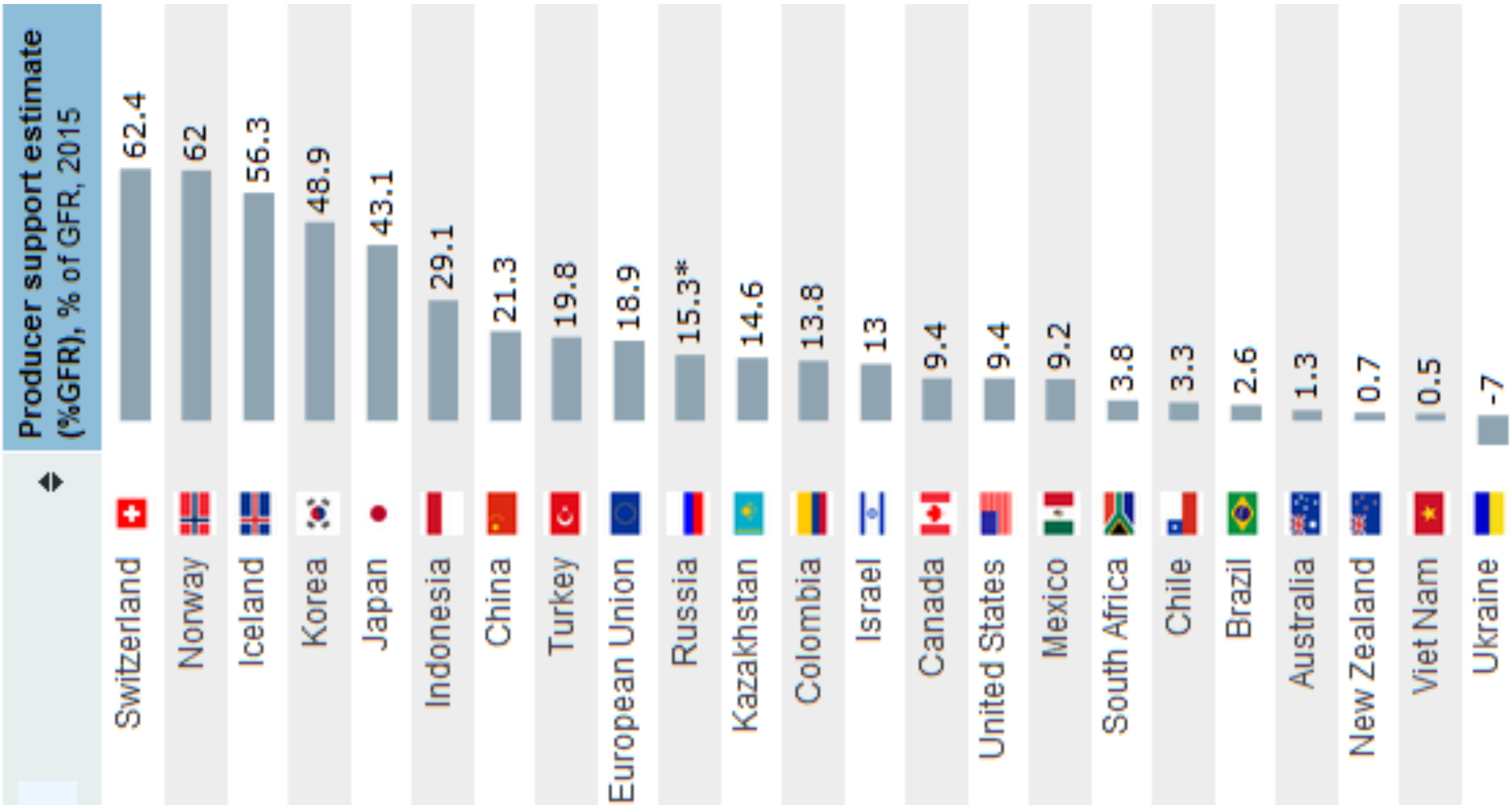
+ as-applied fertiliser map

+ yield map or imagery to estimate biomass

= spatial estimates of C and N dynamics which could be used to support balance calculations.

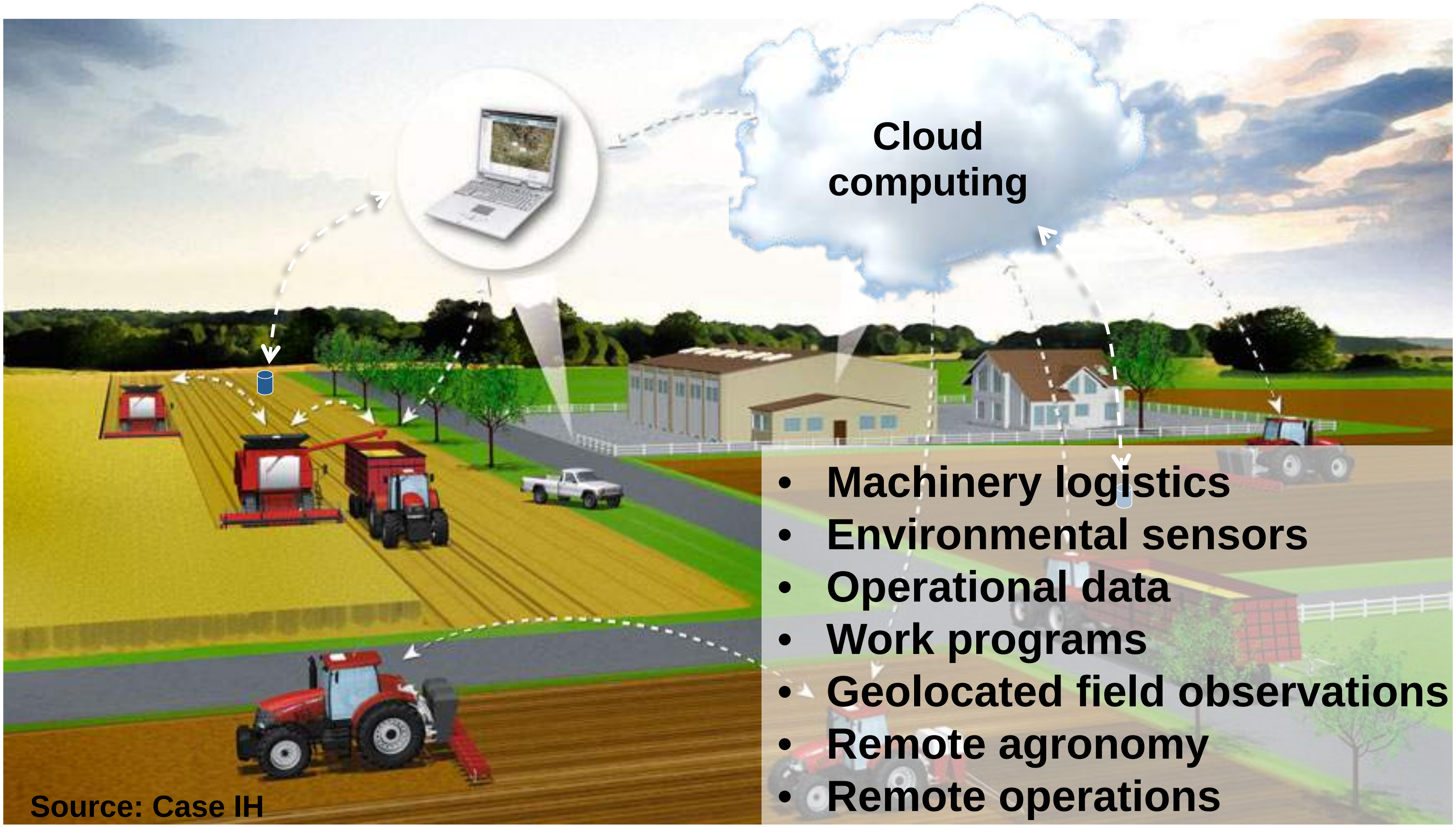
Australian Agriculture

Producer support estimates 2015



OECD (2016). Agricultural Policy Monitoring and Evaluation 2016

Wireless Communication & Cloud Computing



- Machinery logistics
- Environmental sensors
- Operational data
- Work programs
- Geolocated field observations
- Remote agronomy
- Remote operations

Site-specific crop management

There is a large list of important components of a farming operation for which it is useful to have data on the extent of variability in order to optimise production.

- ***For some, such as fertiliser/chemical quality, farmers rely on suppliers to minimise the variation and so 'remove' the need for substantial 'on-farm' monitoring.***
- ***Others, such as crop yield, soil properties and pest and disease outbreaks, vary differently on each farm.***
- ***Local knowledge about variability in these parts of the farming system can be used to build site-specific crop management (SSCM) strategies.***
- ***SSCM can be used to identify and treat areas where yield potential can be improved or better match input use to the natural yield potential across a field or farm.***

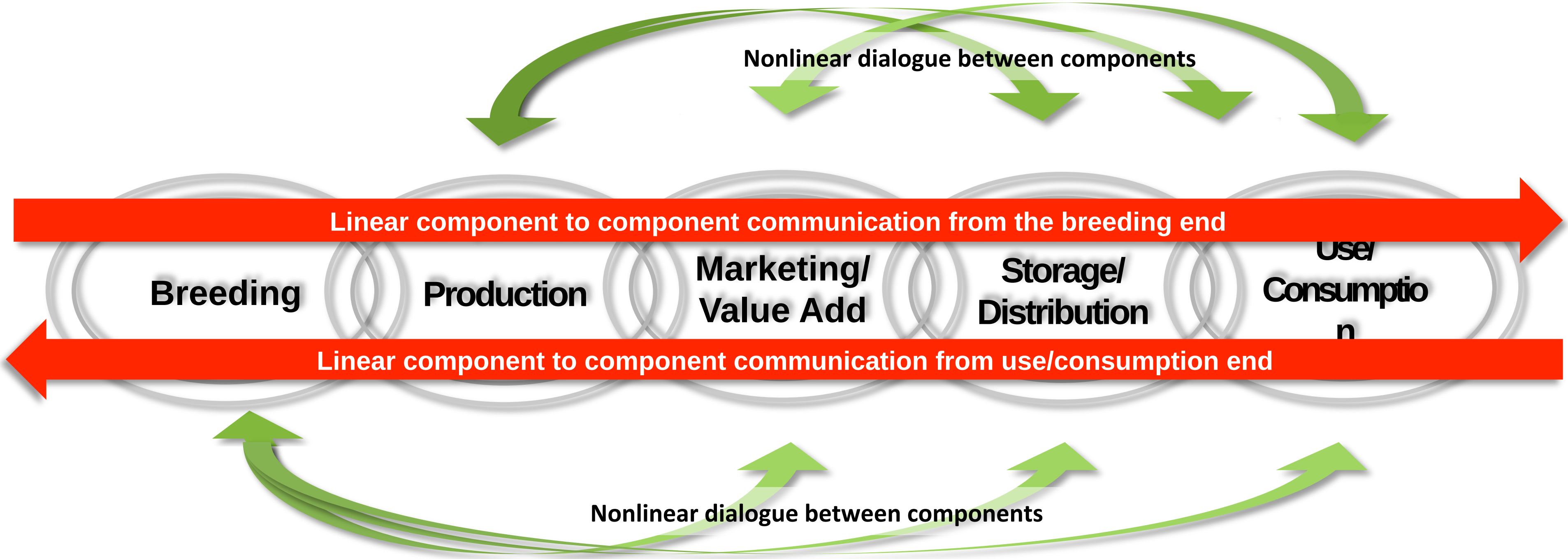
Digital Agri-Food and Fibre Systems - Goals

Meeting the Goals

- These systems will need to identify, gather and use relevant digital data in a more diagnostic way to optimise management and outcomes across all aspects of the breeding and selection (crops and animals), production, marketing, distribution, retail and consumption sectors.

Digital Agri-Food and Fibre Systems

Communication and data sharing between components of the systems



Enable non-linear connections and build extensive system-wide communication that is facilitated by data gathering and utilisation

Production Decision Support – near future needs

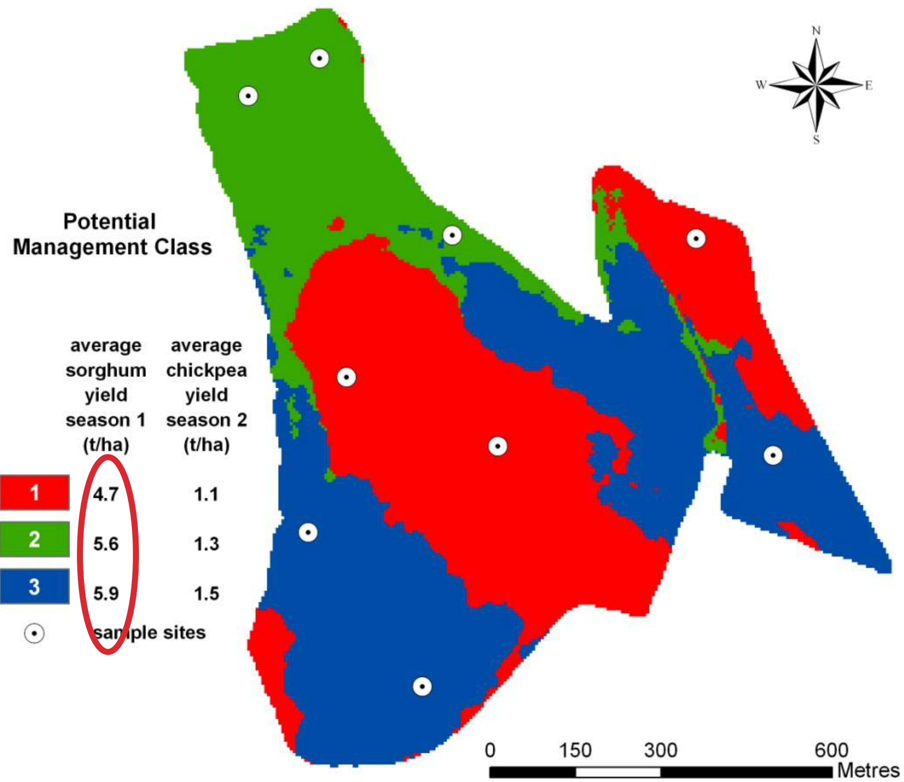
- **Tools that contain the capability of autonomously adapting decision functions and providing farmers with alternative scenarios as input data changes across space and/or time.**
- **Involves the novel integration of relevant data from diverse domains, sources and scales to improve decision management at a fine scale, within bounds of optimising the whole business profitability, and sustainability.**
- **Water use, nitrogen/nutrition and canopy management target issues.**
- **The Augmented Agronomist…..not the Automated Agronomist…..unless the decision/action warrants.**

Optimising crop production decisions

Each crop needs to be investigated for potential benefits

- **Some crops will suit full-scale SSCM**
- **Others will suit SSCM aimed at quality parameters**
  - oTaste (sugars/pungency)
  - oColour
  - oUniformity
  - oSize
- **Others may use the environmental benefits for risk management (over/under fertilisation?) or marketing (environmentally friendly premiums)**
- **Needs to be assessed on the basis of the magnitude, pattern and management/financial impact of variation.**

Potential management classes (PMC)



Investigative samples directed into 3 potential management classes

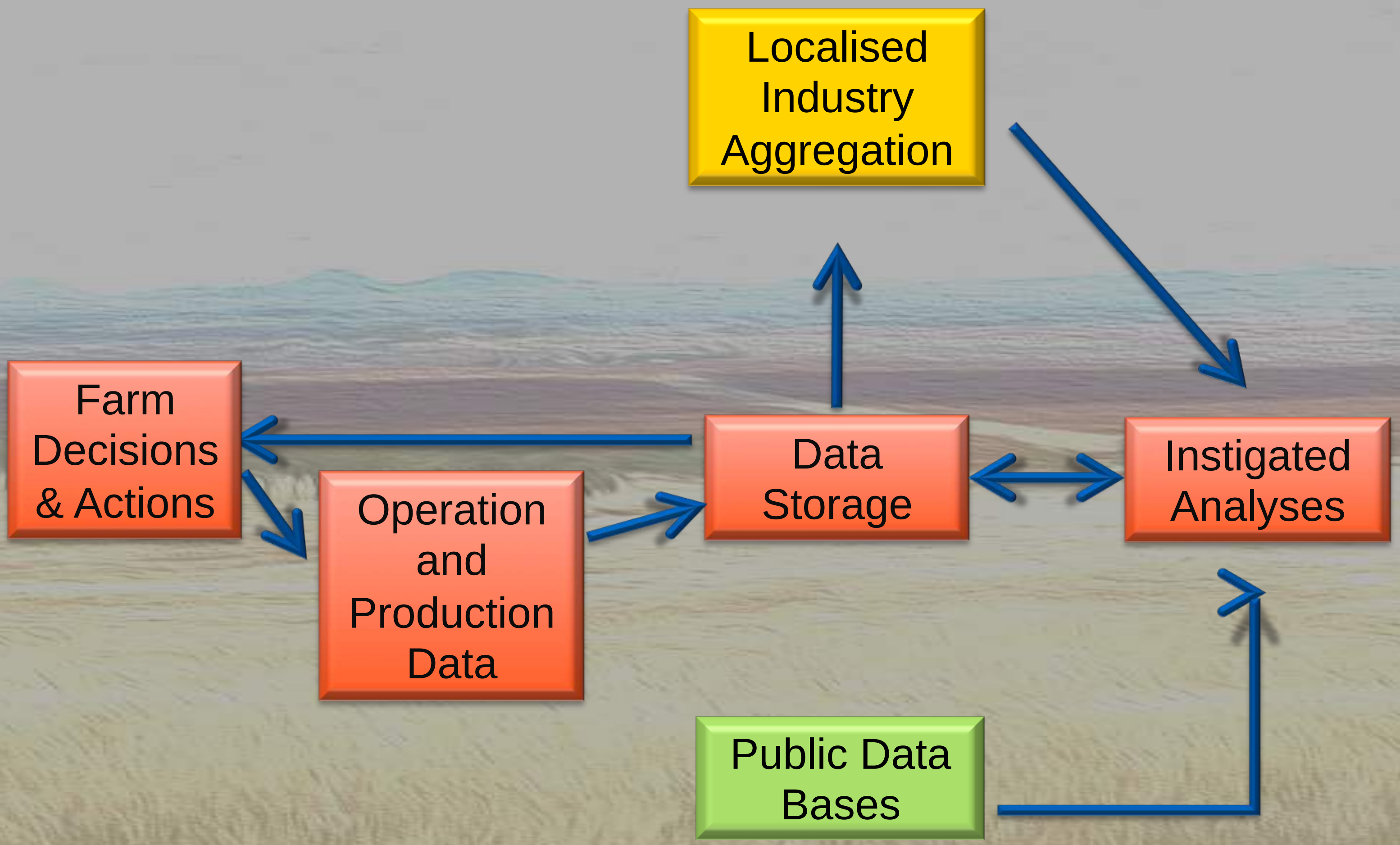
	Class1 (red)	Class 2 (green)	Class 3 (blue)	Field mean
Sorghum yield (t/ha)	4.7	5.6	5.9	5.4

identify differences in soil nitrate levels

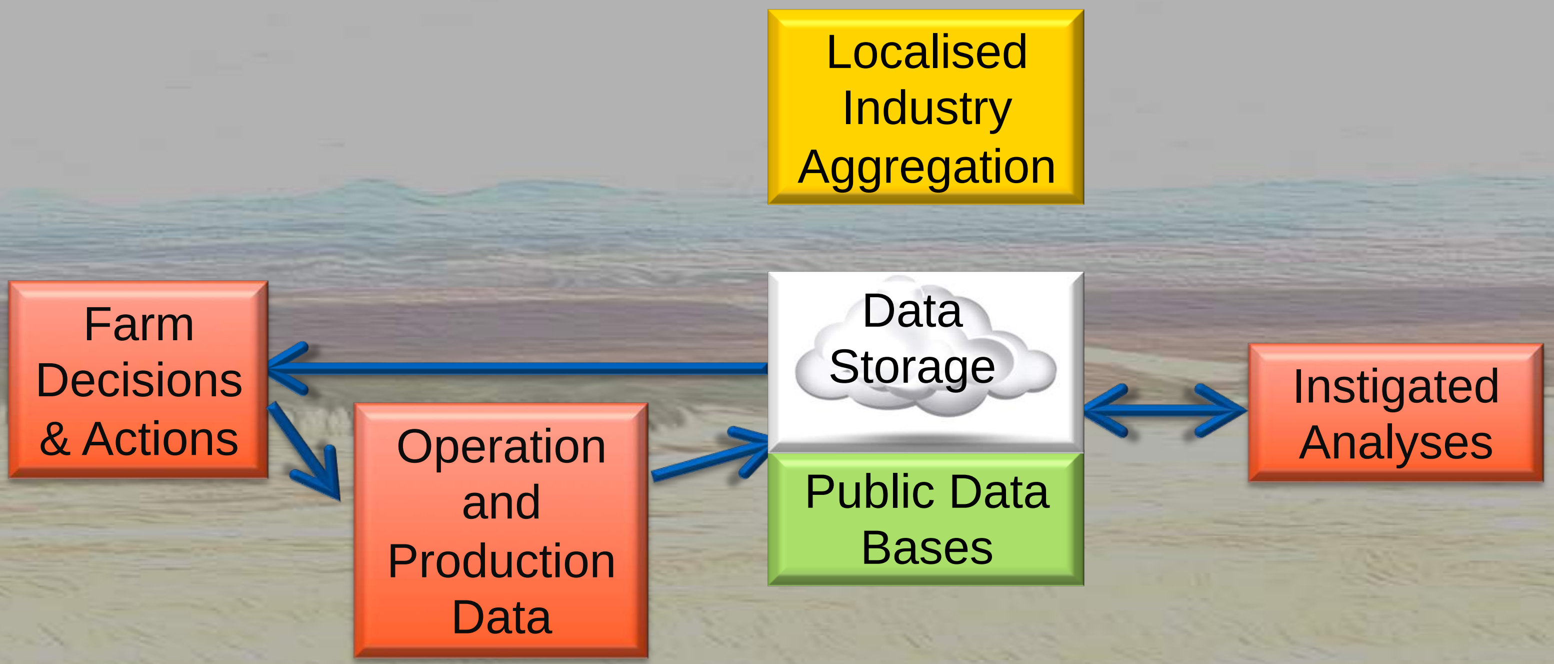
What may be happening here?

Differences in production distinguished between the classes

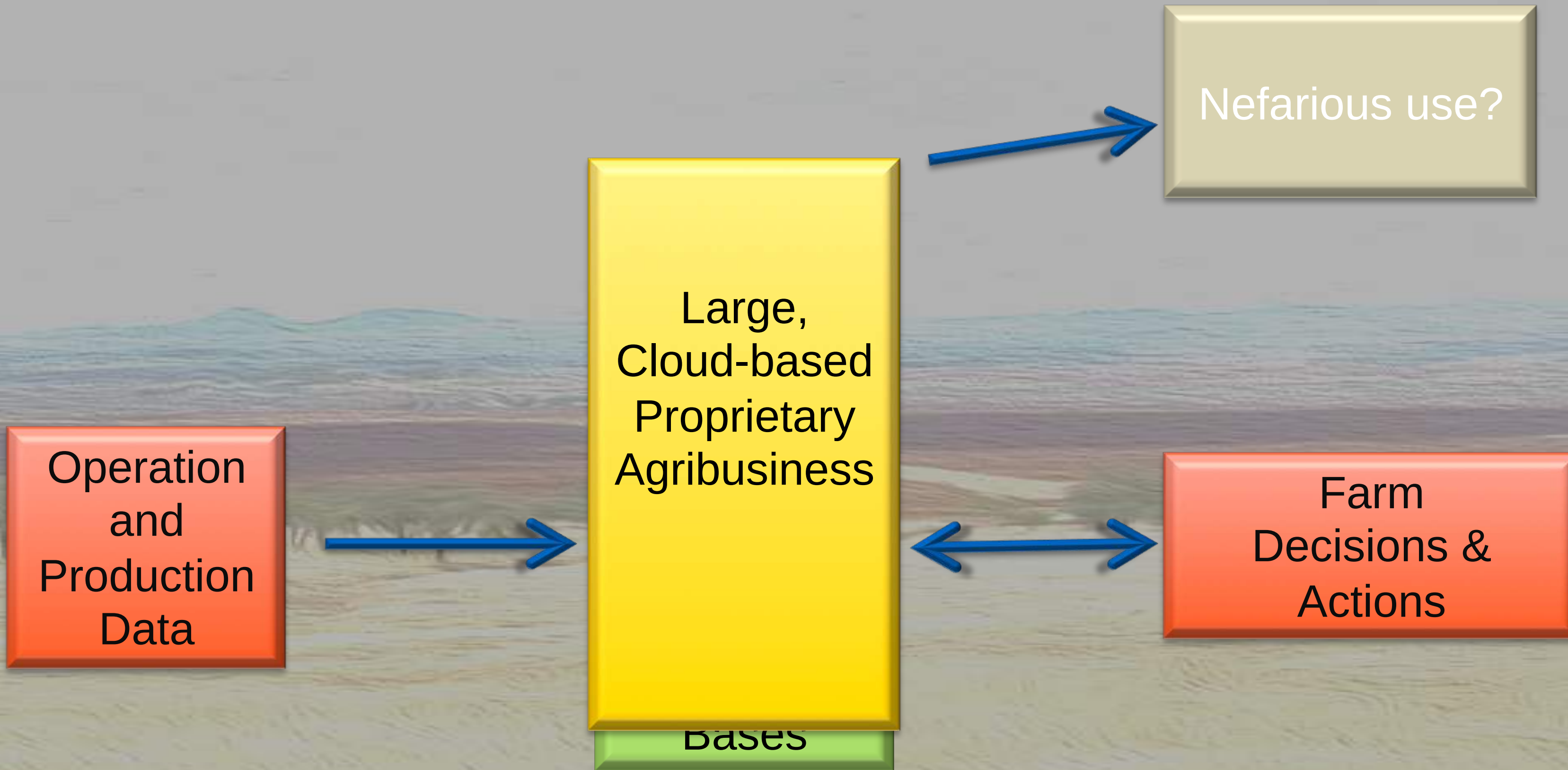
Production Decision Support - future



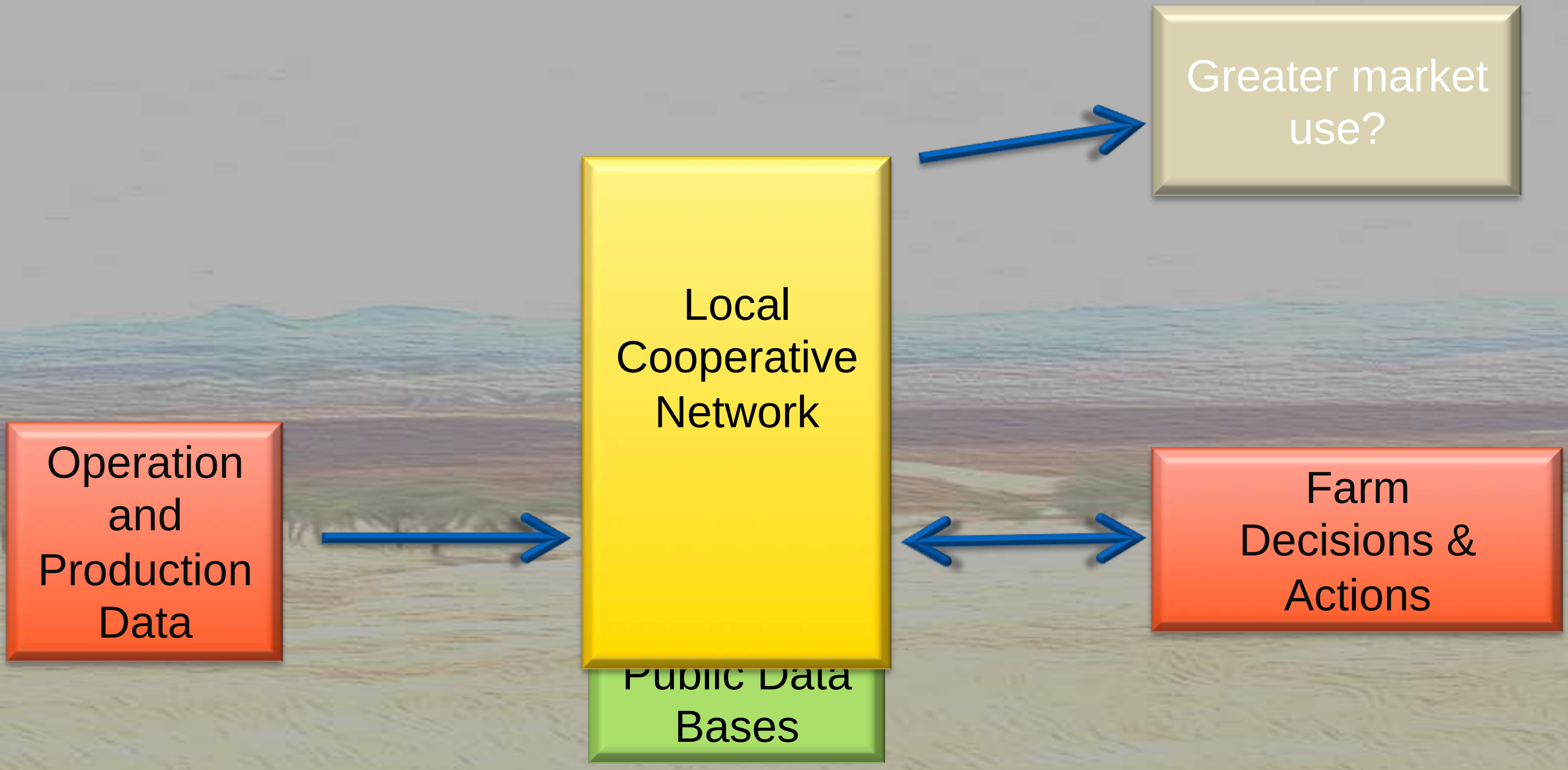
Production Decision Support - future



Production Decision Support – future



Production Decision Support - future



Production Decision Support