Precision Agriculture: Data-Driven Decisions for the Business of Farming

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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.
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.
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

Autosteer vehicle navigation

Beeline Navigator - late 1990’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

Precision Agriculture @ the University of Sydney

Digital data

DGPS
Gamma Radiometer
Dualem 21

gamma
magnetics
yield

terrain
ECa

Precision Agriculture Laboratory
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 protein

Premium/discount

Grain moisture

Gross margin
Calculating TME

Total Metabolisable Energy in Grain

(MJ/ha)

- 15,075 - 20,425
- 20,426 - 25,775
- 25,776 - 31,125
- 31,126 - 36,475
- 36,476 - 41,825
- 41,826 - 47,175
- 47,176 - 52,525
- 52,526 - 57,875
- 57,876 - 63,225
- 63,226 - 68,575

0 100 200 400 600 Metres
Protein monitoring instruments

grain protein (%)
- 7.7 - 8.6
- 8.7 - 9.6
- 9.7 - 10.5
- 10.6 - 11.5
- 11.6 - 12.4
- 12.5 - 13.3
- 13.4 - 14.3
- 14.4 - 15.2
- 15.3 - 16.1
- 16.2 - 17.1
Within-field relationship between GPC and yield

Distribution of correlation coefficients

Local Correlation
- significantly negative
- not significant
- significantly positive

$p = 0.01$
Proximal crop reflectance sensors
Improving the in-season prediction of yield for use in N application algorithms

In-Season

Crop Reflectance

Post-Season

YP0 = Yield without extra fertiliser

YP0 = 1800 × \text{e}^{ \text{NDVI} \times 85 \text{DFP} }
Calculating whole field N requirements

Reflectance

Calibration with crop N

Total crop N

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

$$4 \times 12 \times 1.75 = 84 \text{ kg N/ha}$$

- yield goal
- protein goal
- factor related to the % of N in protein
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

\[ \text{NUE} \left( \frac{\text{kg grain}}{\text{kg N}} \right) \]

\[ \text{Measured total N (kg/ha)} \]

\( \text{Rsq} = 0.85 \)

\( \text{Rsq} = 0.78 \)
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/m² and 14kg grain for every kg of N in the crop. Hitting 550 shoots/m² 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.
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

Research to practice

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
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
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.

Reduce or remove using vehicle navigation aids
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

Autosteer
Ensure that the uniform-rate management options being used suit the average production potential of the farm. Correct any general problems with traffic/water management, soil pH or sodicity, fertiliser applications or weed/pest management. Use maps of variability in soil, crop yield or biomass to get a better idea of the amount and pattern of variability across the farm. Determine if the variability warrants further exploration and management.

Gain an understanding of what is causing the variability and its consequences for input management by analysing soil and/or crop samples taken at locations that cover the range of observed variability. Use this information to identify any areas where yield potential is being restricted by soil factors that can be changed. Variable-rate lime, gypsum, subsoil management or irrigation are options to be considered.

The amount and pattern of any remaining yield variability is mainly due to natural variation in yield potential in combination with weather conditions. If sampling of the soil/crop has shown build up or deficiencies in nutrients in association with this variability, then consider developing variable-rate application (VRA) plans for fertiliser where agronomically viable.

Improve farm production records with spatial information, use data for marketing improvements and work on managing quality to attract premiums.

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**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
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Variable-rate lime application

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

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

78% saving
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.

**Components include:**

- **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

Farm Decisions & Actions

Operation and Production Data

Data Storage

Instigated Analyses
SSCM decision support

- Farm Decisions & Actions
- Operation and Production Data
- Localised Industry Aggregation
- Data Storage
- Instigated Analyses
- Public Data Bases

Diagram shows the flow of data from farm decisions and actions, through operation and production data, to localised industry aggregation, data storage, instigated analyses, and public data bases.
SSCM decision support

Real-time, Adaptable Farm Decisions & Actions

Localised Industry Aggregation

Data Storage

Public Data Bases

Real-time Operation and Production Data
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
A Vision

Gathering soil/crop information during common operations

Soil ECa measured using EM38h

Engine load (% of total power rating)

Vehicle engine load during sowing

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

Wireless Communication & Cloud Computing

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

Source: Case IH
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.
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
  - Taste (sugars/pungency)
  - Colour
  - Uniformity
  - Size
- 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

<table>
<thead>
<tr>
<th>Sample sites</th>
<th>Class 1 (red)</th>
<th>Class 2 (green)</th>
<th>Class 3 (blue)</th>
<th>Field mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum yield (t/ha)</td>
<td>4.7</td>
<td>5.6</td>
<td>5.9</td>
<td>5.4</td>
</tr>
</tbody>
</table>

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

- Farm Decisions & Actions
- Operation and Production Data
- Localised Industry Aggregation
- Data Storage
- Public Data Bases
- Instigated Analyses
Production Decision Support - future

Operation and Production Data

Large, Cloud-based Proprietary Agribusiness

Bases

Farm Decisions & Actions

Nefarious use?
Production Decision Support - future

- Operation and Production Data
- Public Data Bases
- Local Cooperative Network
- Greater market use?
- Farm Decisions & Actions

A flowchart showing the connection between production data, public data bases, local cooperative networks, and market use.
Production Decision Support

Real-time, Adaptable Farm Decisions & Actions

Localised Industry Aggregation

Data Storage

Public Data Bases

Real-time Operation and Production Data