The Big Global Research Issues and Implications for Australia

Rob Norton.
Regional Director ANZ

Better Crops, Better Environment ... through Science

Outline of Presentation

• Introduction to IPNI

• What is the big nutrient management issue?

• Current issues
  – Food Security
  – Nutrient balances & NuGIS

• 4R’s of Nutrient Stewardship
Establishment and Foundation

- Potash Institute and then Potash and Phosphate Institute (PPI) trace back to 1930’s in Canada.
  - Inclusion of N producers
  - Potash & Phosphate Institute (PPI) ceased to exist.
  - PPI’s Board committed its scientific staff to IPNI.
- Not-for-profit international decentralized NGO.
- Purpose to define strategies for appropriate use and management of plant nutrients.
- Australia & New Zealand program began October, 2009.

IPNI is supported by leading fertilizer manufacturers and industry associations

- Agrium Inc
- Agrofert NV (Belgium)
- Belarussian Potash Company
- CF Industries Holdings, Inc.
- Fertilizer Industry Council
- Fertilizers Association of America (FAA)
- Fertilizer Manufacturers Association (FMA)
- IFP
- International Fertilizer Industry Association (IFIA)
- The Fertilizer Institute (TFI)
IPNI Current Programs

- 30 Ph.D. scientists in 10 program areas – 150 projects
  - 9 scientists in North America
  - 17 scientists in International regions
  - 4 in management

IPNI ANZ

- Leadership
- Research
- Education
- Member Support

- Strong alignment with IFA and the goals of FIFA
  - Collaborative projects with Industry stakeholders
  - Science & evidence base for issues relating to nutrient management.
Issues around Nutrients

• Escape to the Environment
  – Eutrophication & Hypoxia
  – Ammonia & air quality
  – Nitrous Oxides as GHG and global warming
  – Nitrate in Drinking water
  – Controlling release (EEF)

• Sustainability of Cropping Systems
  – Soil organic matter, nutrient cycling & soil structure
  – Trace elements in fertilizers
  – Limits to nutrient recycling
  – Resource availability into the future

• Profitability and Productivity of Cropping Systems
  – Food security
  – Rising cost of fertilizer (energy costs)
  – Price/Value of commodities
  – Supply and demand dynamics

• Perceptions of Fertilizers
  – Regulation
  – Soil to Human nutrition

• Integration into Systems
  – Water, Tillage
  – Crop Genotype
  – Mixed Species

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What is the big nutrient management issue?

- Population growth
- Change in diets due to increasing household incomes in developing countries... incomes above $16,000 per yr will rise from 352 mil in 2000 to 2.1 bil by 2030 (World Bank)
- Demand for non-food uses of crops.

Food demand to double by 2050

- Static world land area
- Climate change
- Land for nature
- Energy & Resource availability

World demand for food

- “...food production has to increase 50% by 2013 and double in 30 years...”
  (Source: Global Challenges for Humanity, 2008 State of the Future, Millennium Project)

Need for nutritious foods
Highly urbanised population in developed and developing countries
Implications for Australia

- Australia produces enough food for 60 million people from around 40 Mha of croplands, with 19-22 Mha sown each year
  20 Mt of wheat + 15 Mt of other crops

- Produce more
  – using more land (extensification) and/or
  – produce more using more intensive management (intensification)

- This has been the story of Australian Agriculture.

- Land Limitation
  Policy
  Profitability
  Climate
Response of & constraints for Australia

- Total Factor Productivity of 2.1% per year for the grains industry
  - Age, Education
  - Farm size, intensification
  - Moisture
- Water is a constraint to growth

Mega Environment
Water Use Efficiency Y/WU
(691 crops in the literature)

- China Loess – 9.8 kg/ha/mm
- Medit Basin – 7.4 kg/ha/mm
- NA Plains – 6.1 kg/ha/mm
- SE Aust – 9.9 kg/ha/mm

What is the potential for intensification?

10 kg/ha/mm \( WUE = \frac{Y}{ET} \) (Means)
22 kg/ha/mm \( WUE = \frac{Y(ET-SE)}{ET} \) (Boundaries)

- WUE can be normalised using other variables
  - VPD, Temperature/Daylength – Gives a regional mean/benchmark
- Aim to increase WUE from 10 to 11 (GRDC)
  - Field evaluation of current benchmarks
  - Strategies to raise WUE – Can it be done?
  - Modeled options for increasing WUE from these farms – \( Y/ET \)

<table>
<thead>
<tr>
<th>Current</th>
<th>10.7</th>
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Hochman et al 2010
Intensification – an ongoing story for Australia

• Australia by 2050 – with half current TFP and 10% improvement in WUE – produce ~30 Mt wheat (same 13 Mha)
• Ecological Intensification – using crop management best practices
• Nutrient management will be a key plank along with weed and pest management – bound together with good genetics.
• Resources to produce 30 Mt of wheat & 25 Mt of other grains – 50% higher P removal irrespective of efficiency

  Current P use on grains ~260 kt/year (60% of total P use)
  Current P content of grain produced ~140 kt/year (0.4% of 35 Mt)
  Balance = +5 kg/ha/year

Continental P balance for grains is positive
  – ie more P is applied than is removed

Nutrient Imbalances – a big part of the challenge in an open system

<table>
<thead>
<tr>
<th>Inputs and outputs</th>
<th>Western Kenya</th>
<th>North China</th>
<th>Midwest U.S.A</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>7</td>
<td>8</td>
<td>201</td>
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<tr>
<td>Biological N fixation</td>
<td>?</td>
<td>?</td>
<td>201</td>
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<tr>
<td>Total agronomic inputs</td>
<td>23</td>
<td>4</td>
<td>361</td>
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<tr>
<td>Removal in grain and/or beans</td>
<td>36</td>
<td>3</td>
<td>361</td>
</tr>
<tr>
<td>Removal in other harvested products</td>
<td>59</td>
<td>7</td>
<td>361</td>
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<tr>
<td>Total agronomic outputs</td>
<td>-52</td>
<td>+1</td>
<td>150</td>
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<tr>
<td>Agronomic inputs minus harvest removals</td>
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</table>

Mining versus Pollution

Vitousek et al., 2009, Science
China Figures – IPNI China Office
Nutrient Balances
Australia – NLWRA/ANRA (2001)

Wimmera/Mallee
<-50 kg N/ha
-2 to -10 kg P/ha

Long Term Agronomic Experiments
WBP -9 kg N/ha, +2 kg P/ha
WWW -12 kg N/ha, +9 kg P/ha

Northern Grain Belt – Examples

- Farm surveys 2004-2006
- Net N removal
  - Growers OK for average summer crops
  - Not so good for winter crops
- Underuse of K
  - Annual removals closely related to yield
  - Applications insufficient
- Both N & K budgets show up as low – and declining
- soil reserves

Ball et al. 2010
Example – Dahlen LT Fertilizer (Wimmera)

• 15th Year, mixed crop
• N*P factorial design, multi-rate N and P
• 1996 Colwell P = 24 mg/kg
• 2006
• 9 kg P/ha
  P balanced
  Soil P stable

![Graph showing P balance and Colwell P over time.]

Comprehensive Nutrient Budget Assessment

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<thead>
<tr>
<th></th>
<th>WA</th>
<th>SA</th>
<th>Vic</th>
<th>Tas</th>
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<tbody>
<tr>
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Nutrient Audit as part of ANRA/AAA
Based on 1990’s data

High level of spatial and temporal variability

Linked to soil test data for an assessment of potential nutrient declines, surpluses – ANRA Audit (1990’s)

Do we need something better?
NuGIS overarching objectives

Released August 2010

• Grew from Agristats & Soil Testing Summaries from North America
• Assess nutrient balance and nutrient use efficiency in crop production
• Identify weaknesses in the assessment process
• Web-based resource

NuGIS output and methodology

• OUTPUTS: N, P and K maps at county and watershed levels for:
  – Nutrient balances and removal to use ratios
  – 1987-2007
• Data and calculations:
  – Nutrients in harvested crops
    • Crop production (3-yr average i.e. 2007=2006-2008)
    • Nutrient removal coefficients from IPNI summary of university values
  – Manure nutrients
    • Livestock inventory based on USDA-Ag Census
    • Estimates of excretion and recoverability based on USDA-NRCS
  – Fertilizer applied
    • AAPFCO sales data when available
    • When AAPFCO not available, state total partitioned to counties using Ag Census fertilizer and lime expenditures
• Geospatial techniques used to migrate county data to watersheds for compatibility with water quality models (SPARROW, etc.)
Figure 4.1. Selected P inputs and crop removal for the contiguous U.S., 1987-2007.

\[ P = 0.44 \times P_2O_5 \]
2007 Estimated P Removal to Use Ratio by Hydrologic Region

P removal to use ratio by 8-digit hydrologic unit

- 0.0 - 0.2
- 0.21 - 0.50
- 0.51 - 0.90
- 0.91 - 1.09
- 1.10 - 2.00
- 2.01 - 5.00
- > 5.00
Applications of NuGIS

- Guidance in **nutrient management education**
- A basis for science-based **guidance in marketing** of fertilizers and nutrient management related services
- A tool for integrating nutrient balances in water quality and nitrous oxide emission **modeling**
- Factual spatial and temporal input into environmental **policy development** involving plant nutrients

**Being considered for India, Canada, Brazil, others**

**Basis for assessing Nutrient Best Management Practices**
• Nutrient BMP’s

Research proven practices that have been tested through farmer implementation to optimize production potential, input efficiency, and environmental protection (Smith and Murphy 1991)

International Fertilizer Industry Association (IFA) initiative on fertilizer BMPs

• Goal — ensure plant nutrients are used efficiently and effectively in ways that are beneficial to society without adversely impacting our environment

• International workshop in Brussels (2007) to define principles of FBMPs and a strategy for wider adoption

• Global framework from which FBMPs could be adopted.
Fixen's global FBMP framework (2007)

<table>
<thead>
<tr>
<th>Fertilizer stewardship goals</th>
<th>Economic</th>
<th>Agronomic</th>
<th>Environmental</th>
<th>Social</th>
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</thead>
<tbody>
<tr>
<td>Fertilizer management objectives</td>
<td>Right product</td>
<td>Right rate</td>
<td>Right place</td>
<td>Right time</td>
</tr>
<tr>
<td>Fundamental scientific principles</td>
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<td>2.</td>
<td>3.</td>
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<td>1.</td>
<td>2.</td>
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<td>4.</td>
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<td>2.</td>
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<td>4.</td>
<td>5.</td>
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<td>3.</td>
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<td>5.</td>
<td>1.</td>
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<td>4.</td>
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<tr>
<td>5.</td>
<td>1.</td>
<td>2.</td>
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<td>5.</td>
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Site & grower-specific fertilizer BMPs

**Scientific Principles for Fertilizer Management**

- Right Product, Right Rate, Right Time, Right Place™ system
- 4 R’s approach as a summary

The concept was further developed by IPNI scientists (Bruulsema et al. 2008)

Series in Crops & Soils 2009
Role of 4Rs in nutrient use regulatory and policy developments

- Being implemented within the Alberta’s N$_2$O reduction protocol (NERP) and under consideration in other provinces
- NERP – a proposed system to help reduce on-farm emission of N$_2$O
  - designed to reward producers for adoption of sustainable practices reducing emission of nitrous oxide per unit of production

So – will we feed the 9 billion?

- What a great time to be in the fertilizer industry
- Increased productivity to maintain grower viability & create wealth – 4R’s
- Australia is lucky – it has a choice about how many to feed
- Role for Australian Science and business at an international scale – excellent linkages (ACIAR, GRDC, AusAid, Crawford, CGIAR)
- In-country programs are a key
  - Coffee production in Peru (BC #1 2007)
    - Yields with balanced nutrition program
  - Maize Production in Malawi
    - rose from 1.2 to 3.4 Mt with seed and fertilizer
Food Security encompasses food quantity, food nutritional value, food safety and food supply
Grain Nutrient Levels
(all in mg/kg)

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>K</th>
<th>S</th>
<th>Ca</th>
<th>Mg</th>
<th>Zn</th>
<th>Fe</th>
<th>Cu</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>International</strong></td>
<td>3600</td>
<td>4000</td>
<td>1700</td>
<td>894</td>
<td>1341</td>
<td>31</td>
<td>59</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>CV</td>
<td>53%</td>
<td>20%</td>
<td>24%</td>
<td>61%</td>
<td>33%</td>
<td>41%</td>
<td>62%</td>
<td>61%</td>
<td>71%</td>
</tr>
<tr>
<td><strong>Australia</strong></td>
<td>3300</td>
<td>4600</td>
<td>1700</td>
<td>421</td>
<td>1281</td>
<td>23</td>
<td>37</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Australia CV</td>
<td>21%</td>
<td>14%</td>
<td>12%</td>
<td>21%</td>
<td>10%</td>
<td>32%</td>
<td>19%</td>
<td>25%</td>
<td>58%</td>
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- International Values taken from IPNI survey of 130 samples from India, China, Canada, USA, Russia.
- Australian values taken from IPNI survey of 130 samples from NVT experiments in 2009 from Southeastern Australia. Lowest values in Mallee and EP samples (19 mg/kg)

*Desired range for human health on grains based diet > ~35 mg/kg*
Response to Zn

Yield Response to 7.5 kg Zn – 2 of 6 sites
Grain Zn Increase on 5 of 6 sites
DTPA Zn test available but difficult to find yield responsive sites

Biofortification of wheat through conventional breeding & use of zinc fertilizer

Nutrition objectives – get Grain Zn to 35 mg/kg

Agronomic approach:
- Basal & foliar zinc application can dramatically increase grain zinc, but has a minor effect increasing grain yield
- High seed zinc - vigour, biotic/abiotic stress tolerance

Breeding approach
- For most zinc target crops possible, however, cereals are sensitive, load little zinc into seeds
- Positive correlation between grain zinc and % protein > negative effect on grain yield (in particular wheat)

FIT IN THE VALUE CHAIN FOR FARMERS
- Good Idea: Important to do: Capable of impact: Value to grower?