Understanding Nitrogen Fertiliser Use in Dairy Systems

Richard Rawnsley
Dairy Centre Leader
TIA | School of Land and Food
University of Tasmania
Private Bag 3523 Burnie, TAS 7320 Australia
+61 3 6430 4504
0428 501 972
Richard.Rawnsley @utas.edu.au
www.tia.tas.edu.au

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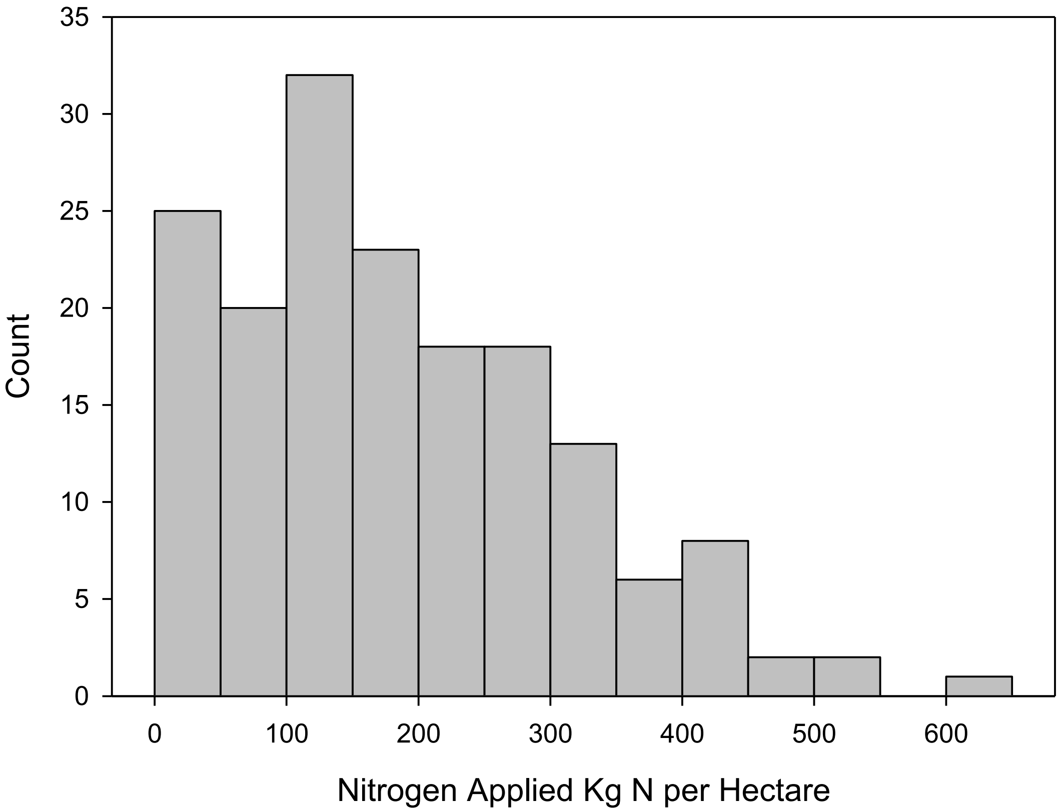
Tasmania
Explore the possibilities

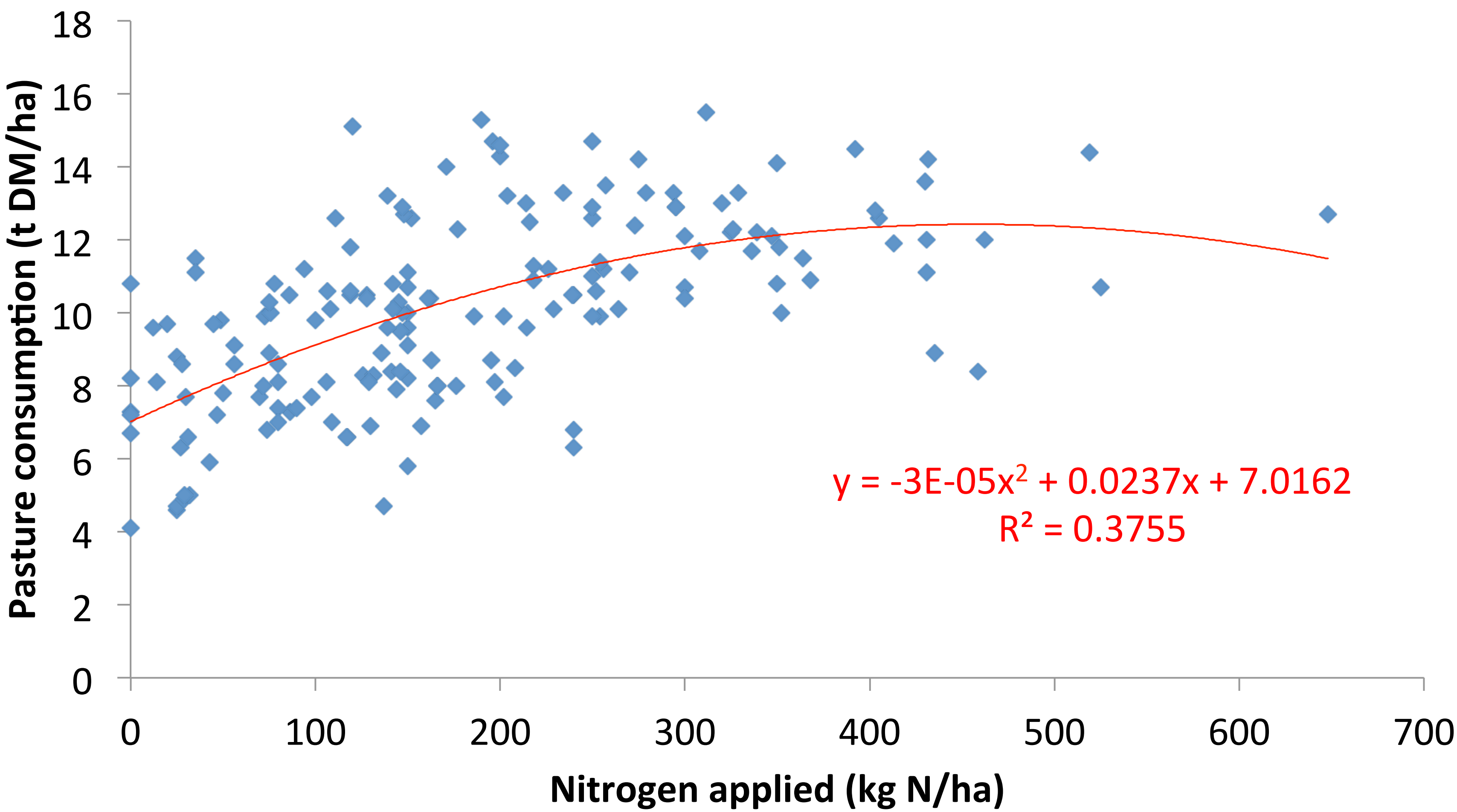
Nitrogen use on Tasmanian Dairy Farms



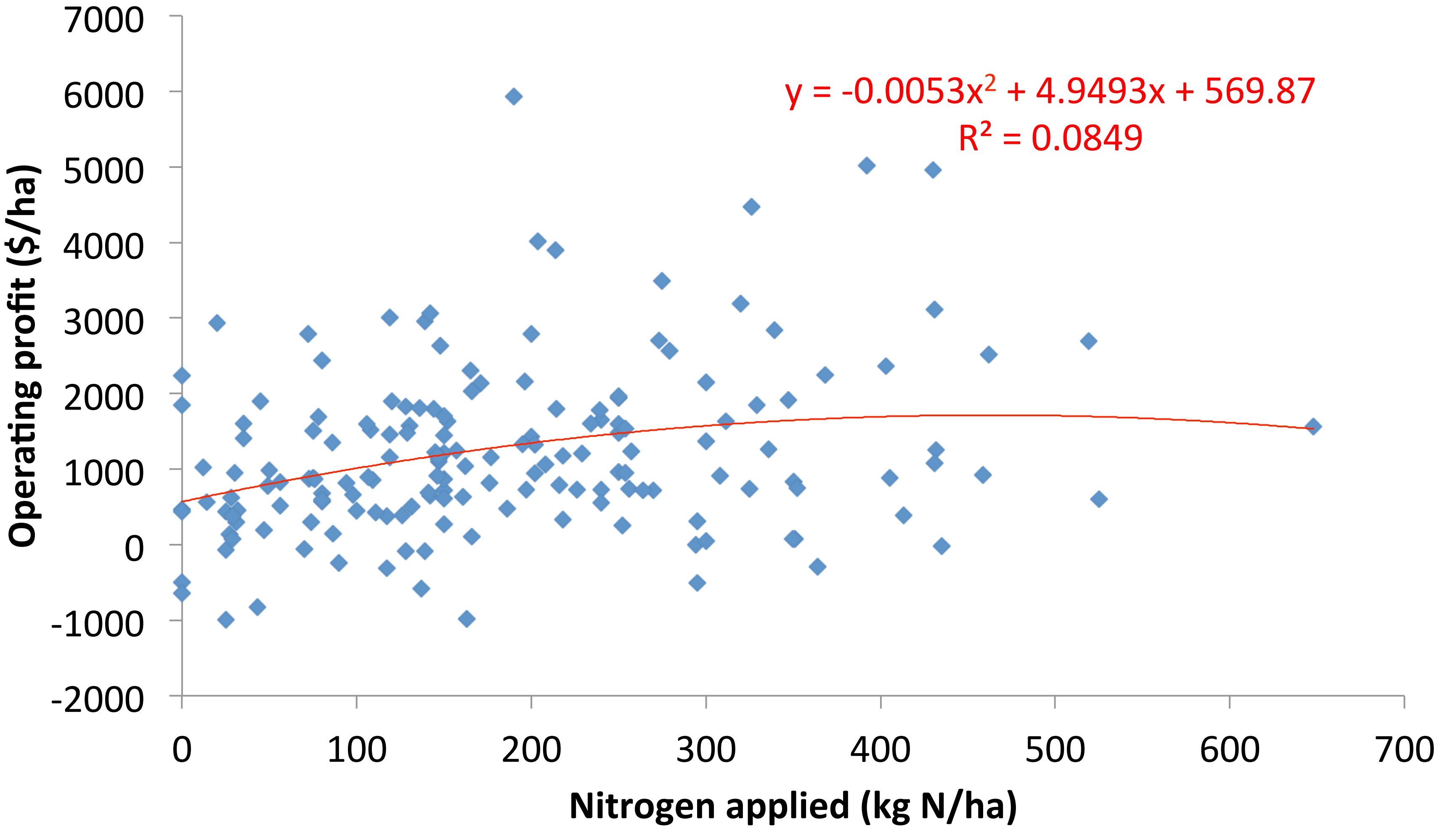
Average	185 kg N/ha
10th Percentile	31 kg N/ha
25th Percentile	89 kg N/ha
50th Percentile	151 kg N/ha
75th Percentile	255 kg N/ha
90th Percentile	351 kg N/ha

Source (DBOY 2006-2010, RedSky analysis)

Nitrogen use on Tasmanian Dairy Farms



Nitrogen use on Tasmanian Dairy Farms



The Role of Nitrogen

- All living organism require Nitrogen (N)
  - Essential constituent in chemical structure of proteins and nucleic acids
- Essential for pasture growth
  - Generally between 2.5 and 4.0% in ryegrass pastures
- For pasture N must be in the form of either ammonium of nitrate
- Generally speaking intensive farming system rely on the provision of additional N
- It takes about 600kg N to grow 12t DM/ha regardless of where the N comes from

Nitrogen Cycle

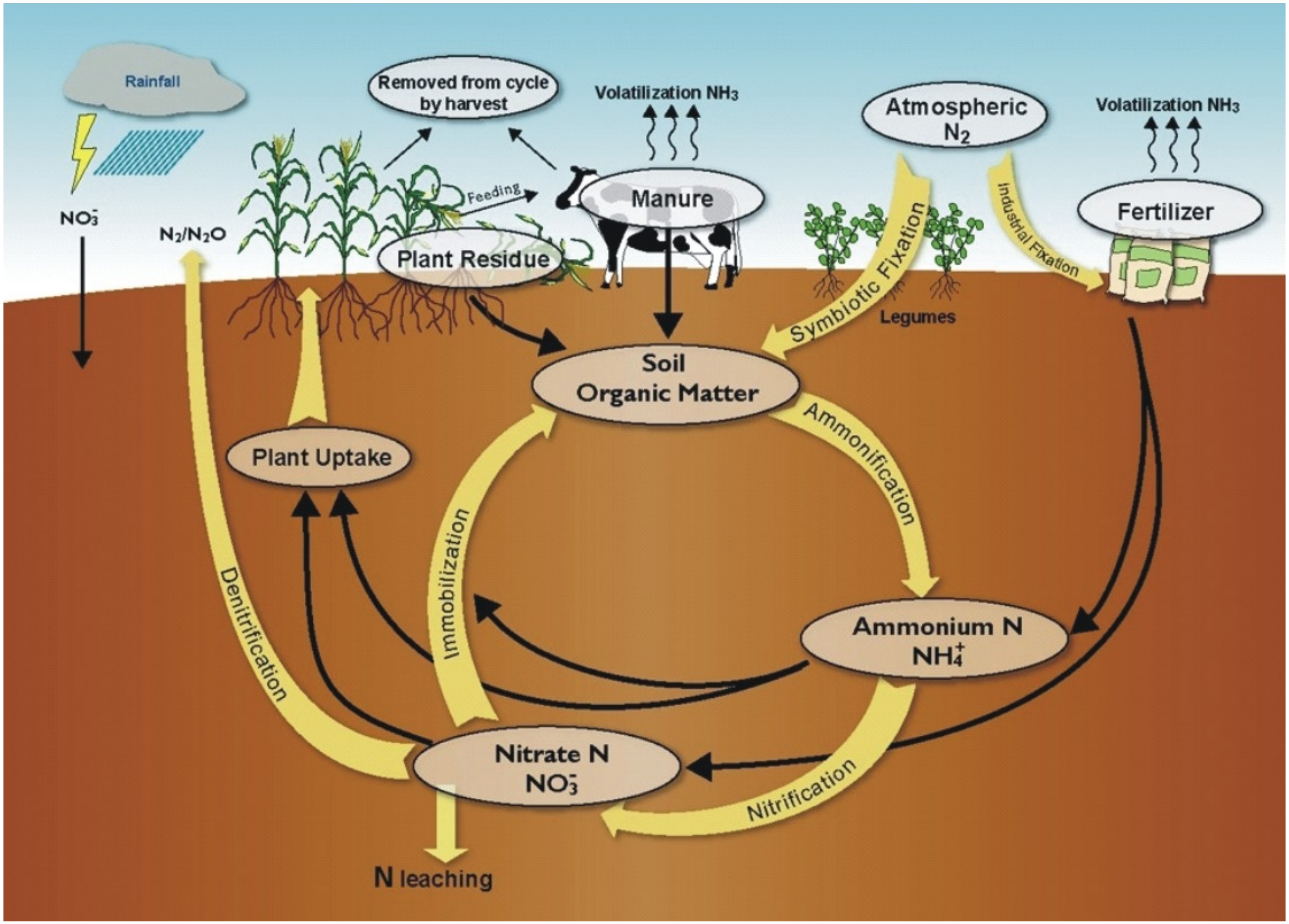
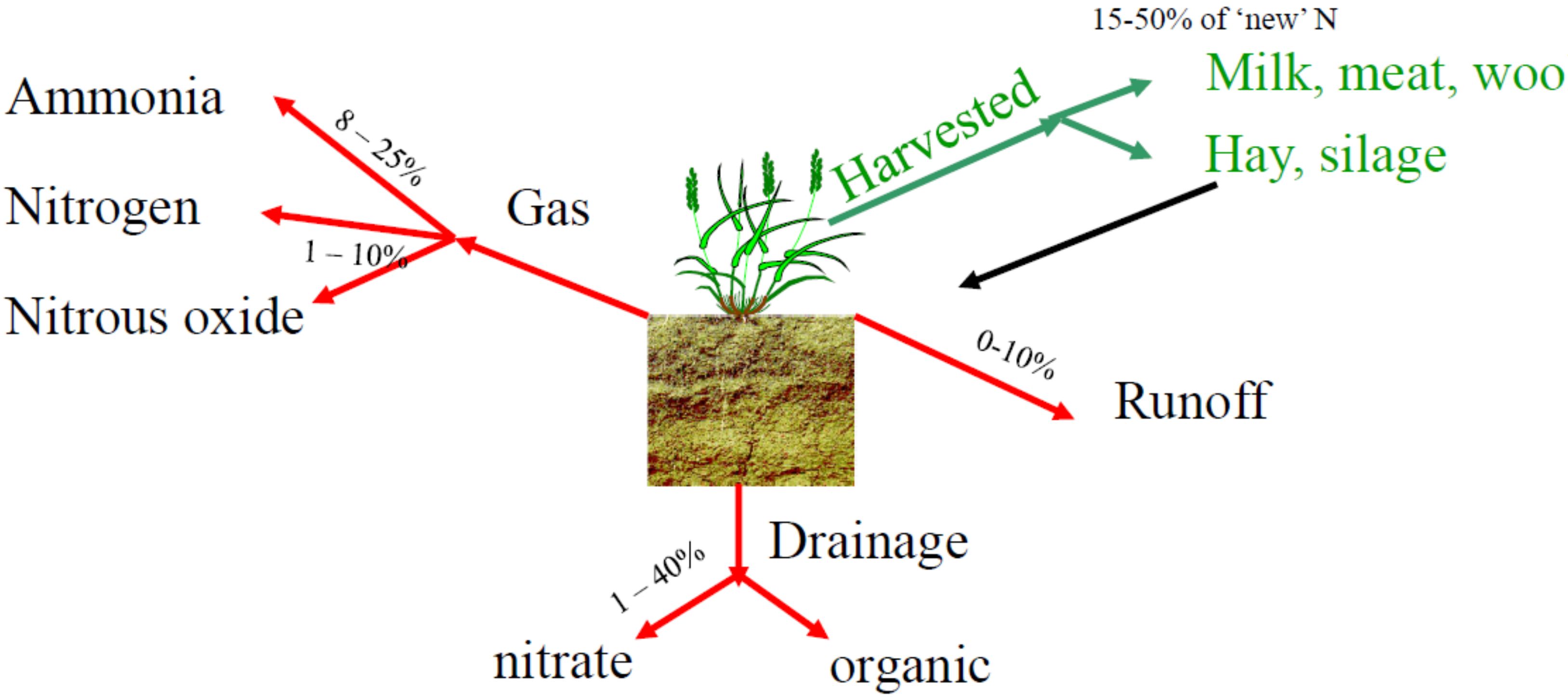


Photo Courtesy of UW Nutrient and Pest Management Program.
Source http://fyi.uwex.edu/discoveryfarms/page/7/

Nitrogen Cycle

- Soil nitrogen exist in three general forms –organic nitrogen, ammonium (NH_4^+) ion and nitrate (NO_3^-) ions .
- Nitrate and ammonium ions are taken up the plant roots but they differ in their mechanism.
  – Nitrate is an anion, is not adsorbed by the colloidal material and is therefore mobile in solution. It is easily accessible but also susceptible to leaching and denitrification.
  – Ammonium is a cation and is retained by cation exchange on the clay and organic matter. Less mobile, less accessible and less susceptible to loss than nitrate. However ammonium is progressively converted to nitrate (nitrification).

Nitrogen – Where does it go to ?



Only 30 to 40% of total N is fully recycled!

Source Eckard 2004

Nitrogen Response Efficiency

- Nitrogen response efficiency is expressed as the amount of additional pasture grown divided by the amount of N applied.
  - For example:
    - Apply 50Kg N/ha and produce 1500 kg DM/ha.
    - Apply no nitrogen and produce 1000 kg of DM/ha
    - Additional growth due to Nitrogen is 500kg DM (1000 – 500).
    - N response efficiency is additional growth divided by the amount applied. That is 500 kg DM/50kg N =10 kg DM/ kg N
    - At $1.50 per kg N to apply the cost of additional pasture is
      - $1.50/ 10 kg DM = 15c per kg DM or $150 per t DM.

Factors affecting response to Nitrogen

- Soil Temperature
  - Pasture will respond to nitrogen as long as soil temperature are above 4^{o}C. General rule is if the pasture is growing you will get a response to nitrogen
- Soil Moisture
  - If soil moisture is depleted this will limit pasture growth an in turn limit responses to N fertiliser
- Basal Fertility and Species Composition
  - For pasture to respond well to N, other soil nutrient and pasture composition must not be limiting
- Current soil N status

Nitrogen research

Hypothesised that:

a. part of the variability in the response of pastures to the application of nitrogen can be attributed to the soil inorganic N status prior to the application of mineral fertilisers and

b. then it may be possible to determine optimum N application rate based on current soil N status.

Also Hypothesised that:

a. That timing of N fertilise application during winter does not influence the efficiency of nitrogen response rate .

Study design

- experimental area grazed over the Autumn/winter period.
  - 29th April, 4th June, 20th July and 1st September
- Three nitrogen application rates applied immediately following each of the first three grazing events to each main plot
  - 0 (total N applied 0 kg N/ha)
  - 50 (total N applied 150 kg N/ha)
  - 100 (total N applied 300 kg N/ha)
- Each main plot was divided into six 6 sub-plots. Following grazing on 1st September application rates (0, 20, 40, 60, 80 or 100 kg N/ha) was then randomly allocated to each subplot
- The experiment was then allowed to grow to 2.5 to 3 leaves then was grazed and then allowed to grow to 2.5 to 3 leaves again.

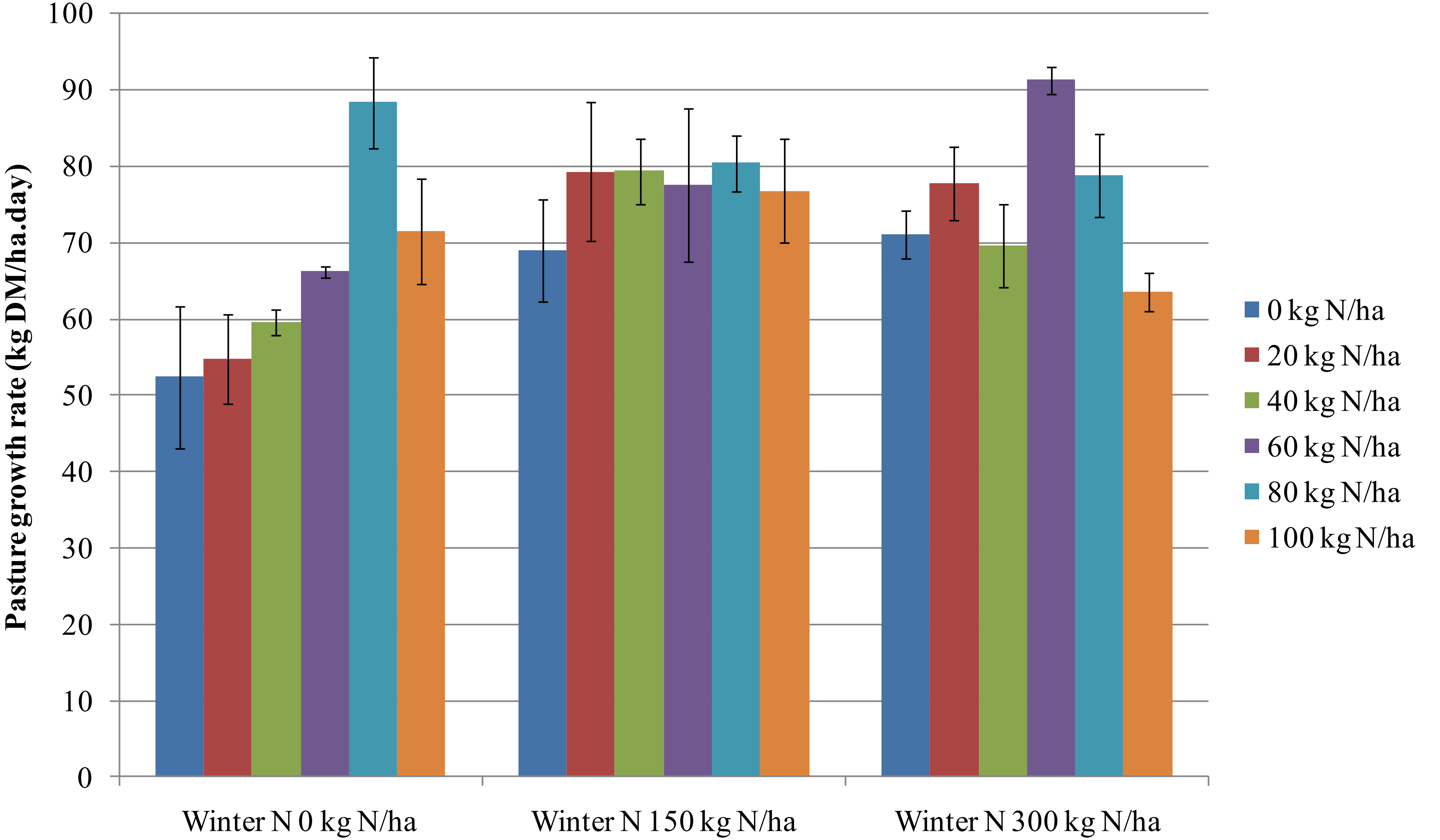
Results

Soil N status and pasture sap NO_3 concentration after the application of winter N treatments and prior to the application of spring N treatments.

	Total soil inorganic N (kg/ha)	Sap NO_3 (ppm)
Depth (mm)	0 to 300	
Winter N (kg N/ha)		
0	10.5 (0.9)	445 (112)
150	21.9 (1.3)	517 (111)
300	54.6 (14.0)	675 (78)
P value	<0.05	ns

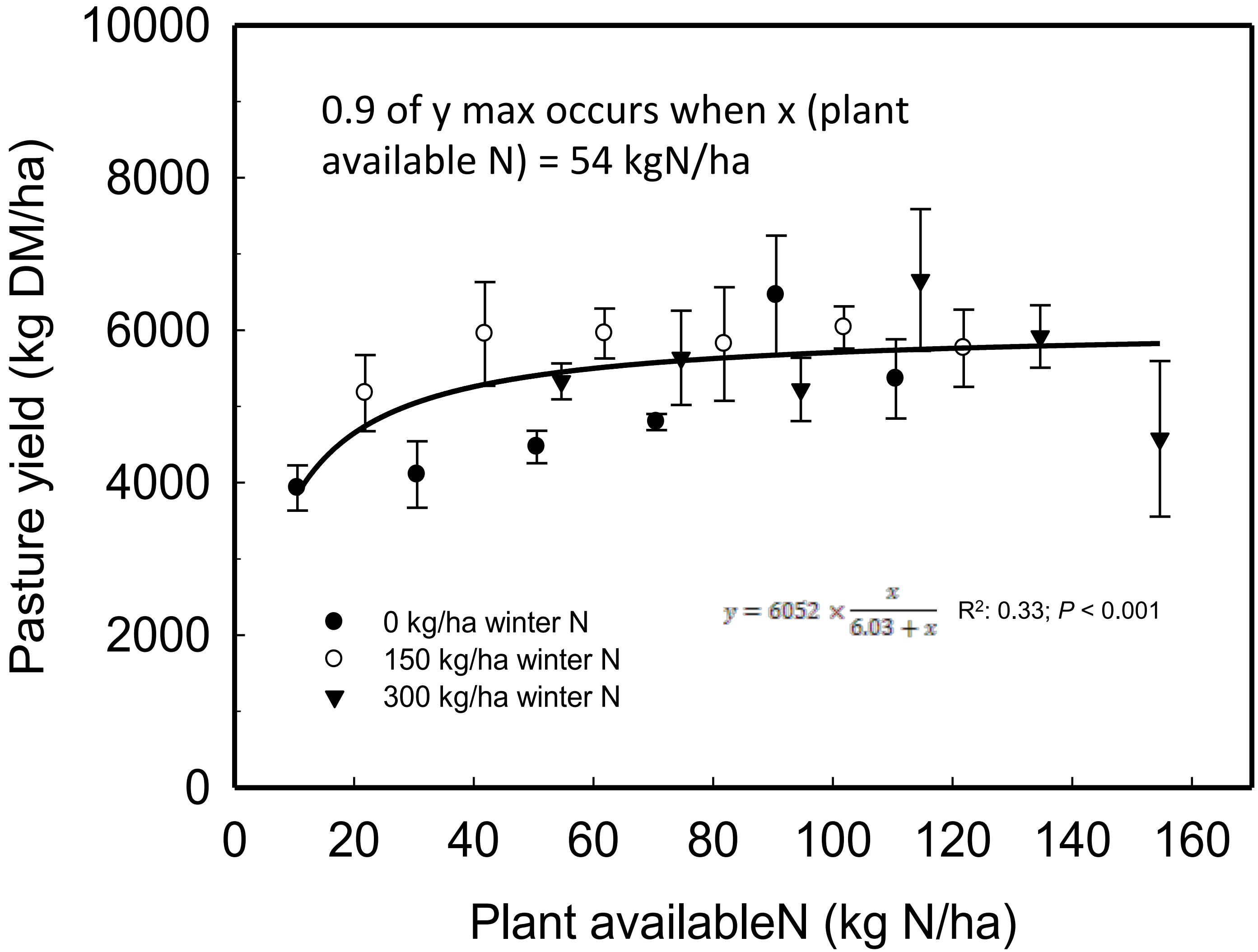
Values in parentheses are the standard errors around the mean

Results



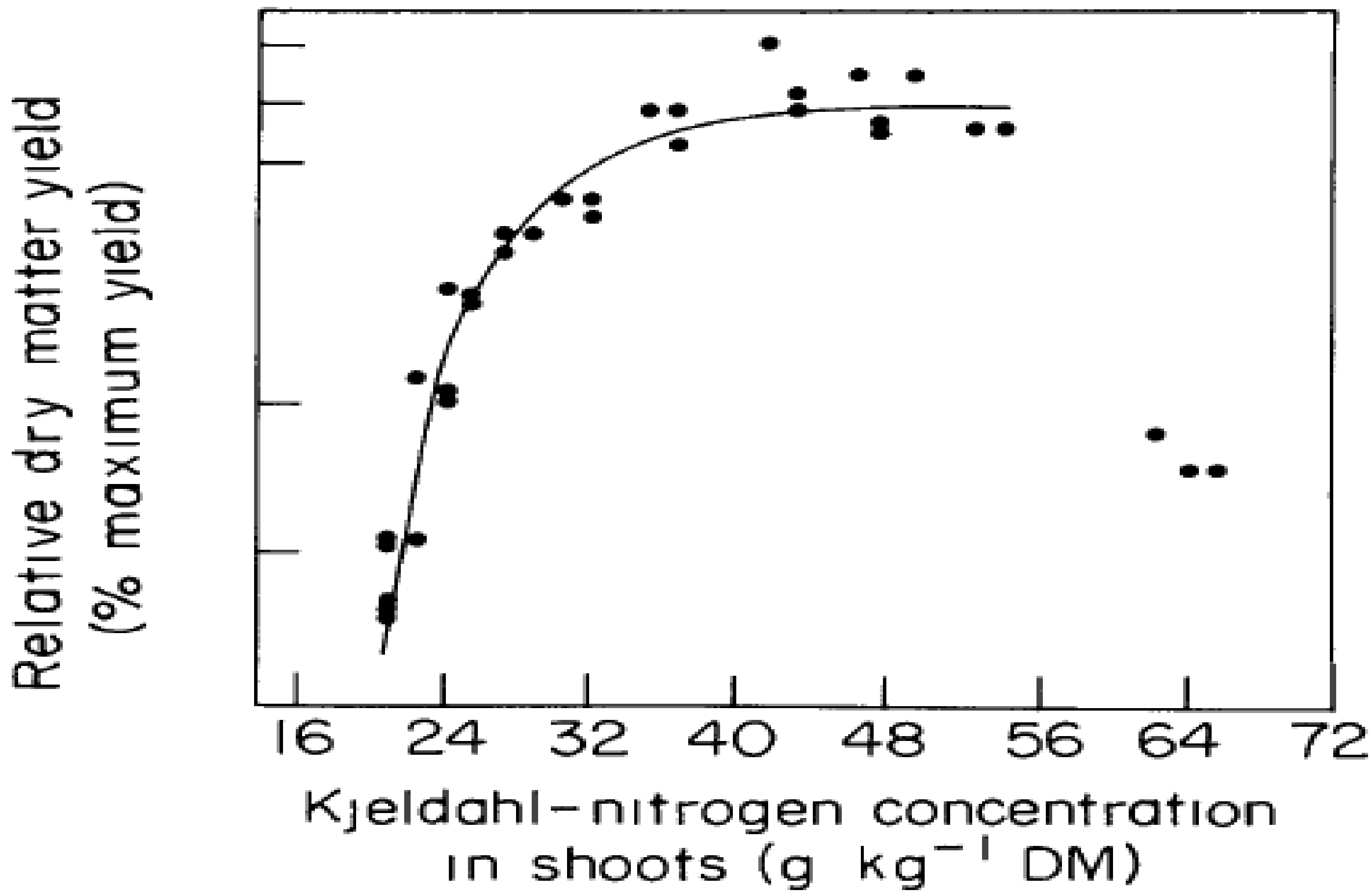
Pasture growth rate (kg DM/ha.day)
100
90
80
70
60
50
40
30
20
10
0
Winter N 0 kg N/ha
Winter N 150 kg N/ha
Winter N 300 kg N/ha
0 kg N/ha
20 kg N/ha
40 kg N/ha
60 kg N/ha
80 kg N/ha
100 kg N/ha

Results



0.9 of y max occurs when x (plant available N) = 54 kgN/ha
$y = 6052 \times \frac{x}{6.03 + x}$ R^2: 0.33; $P < 0.001$
0 kg/ha winter N
150 kg/ha winter N
300 kg/ha winter N
Pasture yield (kg DM/ha)
Plant availableN (kg N/ha)
0
2000
4000
6000
8000
10000
0
20
40
60
80
100
120
140
160

What about plant N concentration ?



Relation between Kjeldahl-nitrogen concentration in shoots and relative dry matter yield of perennial ryegrass. Source: Smith *et al*. (1985).

Study design

- Two locations.
  - Elliott and Mella
- Nitrogen applied at leaf stage (main plots)
  - 0, 0.5, 1, 1.5 and 2 leaves
- Each main plot was divided into six 5 sub-plots for nitrogen fertiliser application rates
  - 0, 25, 50, 75 and 100 kgN/ha
- The experiment was allowed to grow to 3 leaves for two growth periods

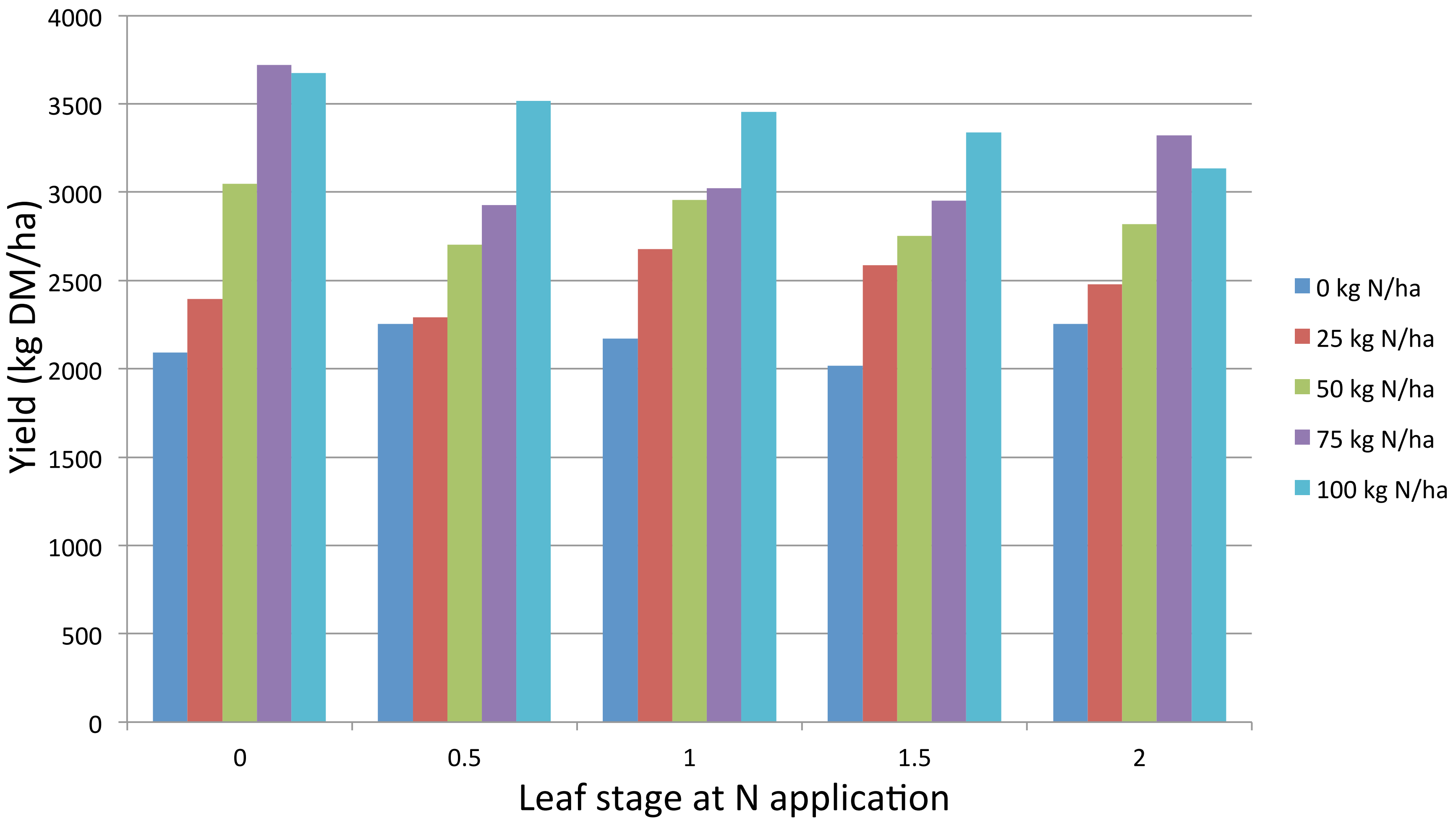
Study design

Soil test results for the experimental sites

	Units	Mella	Elliott
Nitrate Nitrogen	mg/Kg	82	1.4
Phosphorus Olsen	mg/Kg	43.6	13.4
Potassium Colwell	mg/Kg	210	150
Sulphur	mg/Kg	9.3	25
Organic Carbon	%	5.4	6.0
pH Level (CaCl2)	pH	5.0	5.3
pH Level (H2O)	pH	5.6	5.9

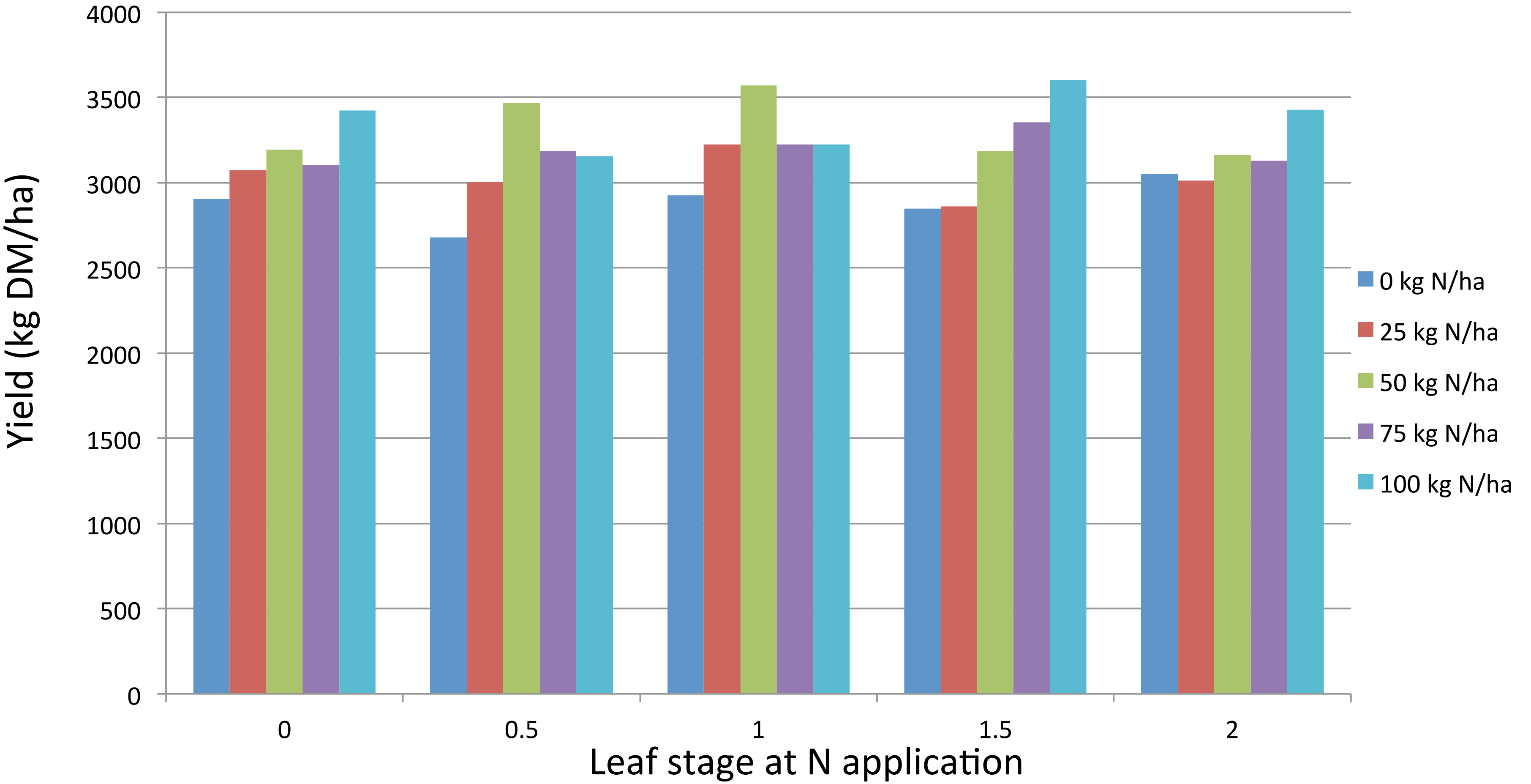
Results – 2011

Elliott – total yield (two harvests)



Results – 2011

Mella – total yield



Results – 2011

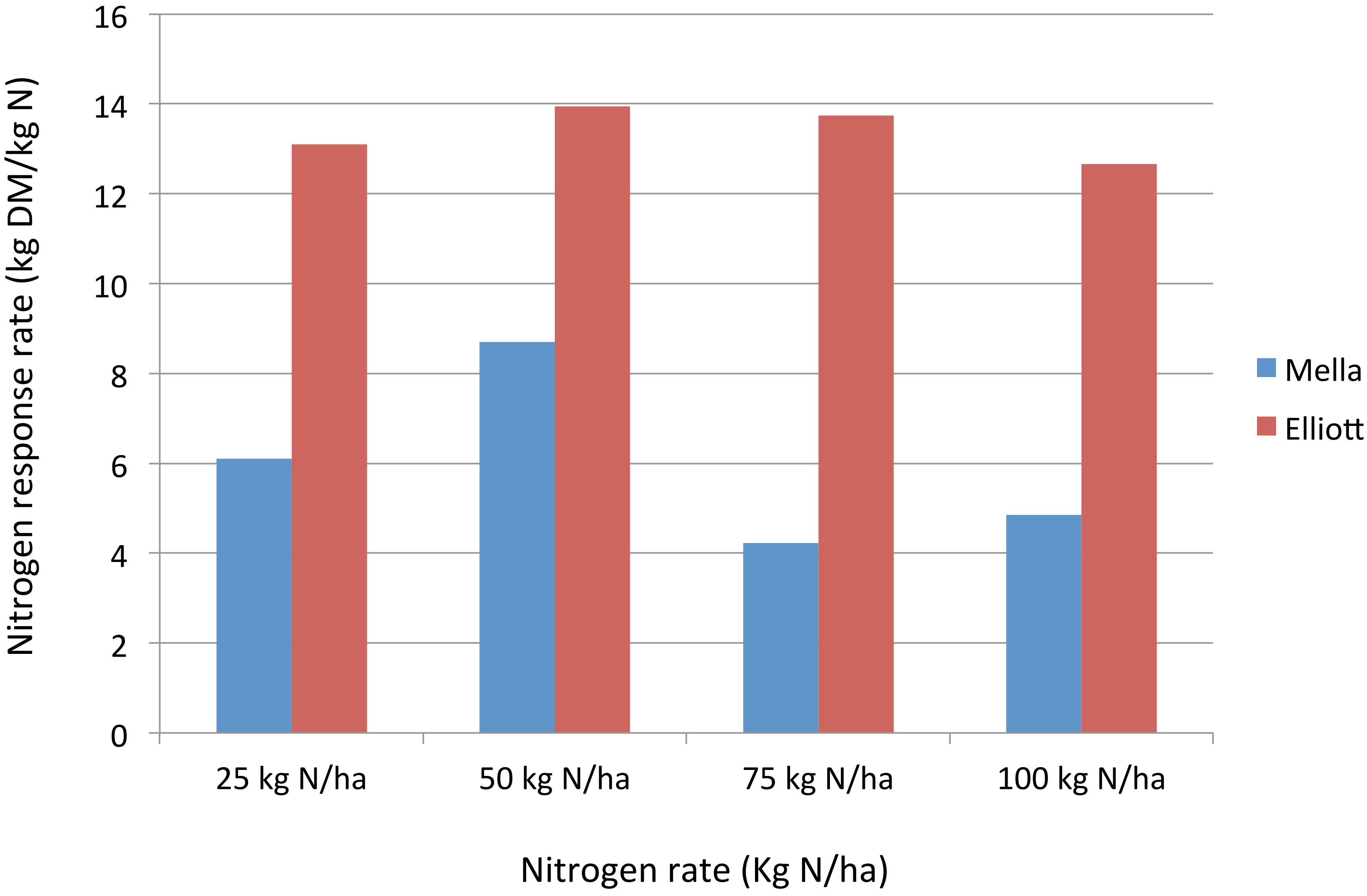
Factor	Elliott	Mella
Leaf stage	0.216	0.671
Nitrogen	**<.001**	**<.001**
Leaf stage x Nitrogen	0.276	0.257

Total Yield

Location	0kg N/ha				100 kg N/ha
Elliott	2159^{a}				3425^{e}
Mella	2880^{a}				3366^{c}

What is the nitrogen response efficiency here for the two sites

Results



Nitrogen response rate (kg DM/kg N)
16
14
12
10
8
6
4
2
0
25 kg N/ha
50 kg N/ha
75 kg N/ha
100 kg N/ha
Nitrogen rate (Kg N/ha)
Mella
Elliott

Lessons so far

- Anecdotal evidence that N soil status may provide some indication of N response rate and that the response rate to nitrogen is influenced by current soil status
- In the two environments examined, the timing of N application during winter did not influence N response rate so long as sufficient time (at least 1-leaf regrowth period) is provided. This provides flexibility to winter N applications.
  - But be careful, elevate N concentration in pasture at grazing likely when applied between the 1 and 2 leaf regrowth compared to between 0 and 1 leaf regrowth stage
- The optimum N response rate coming into spring is 50 to 60 kg N/ha of available soil N and that diagnostic assessment of N availability prior to spring may provide some indication of N required.
- Reliability and accuracy of soil N tests requires further research and development.
- Development of N response calculator

Development tools

tiar
TASMANIAN INSTITUTE OF AGRICULTURAL RESEARCH

Predictive N fertiliser response rate calculator

tasdairyprojects

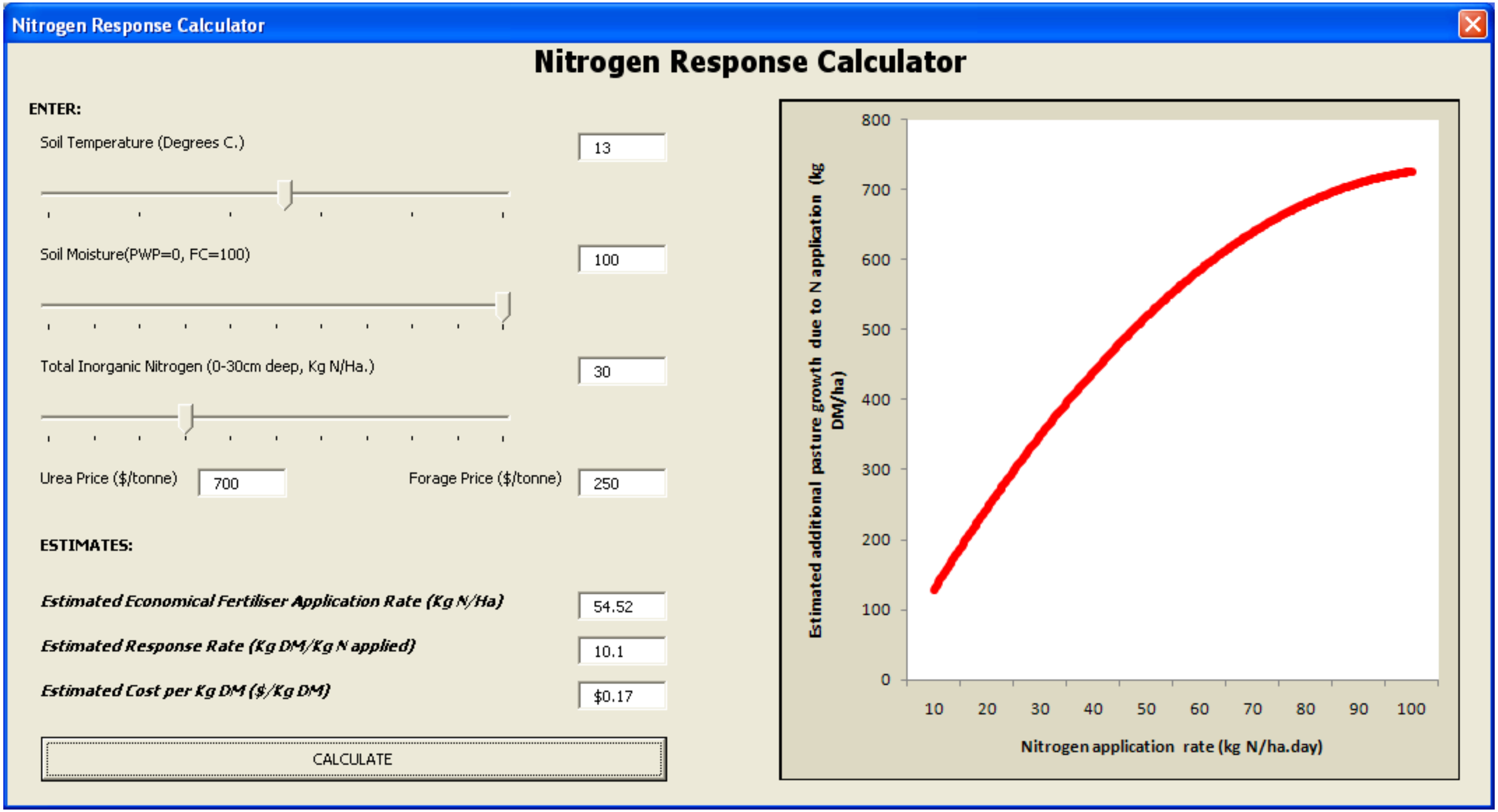
DAIRY AUSTRALIA
Delivering for the dairy industry

Predict your N fertiliser response rate based on your soil temperature, soil moisture content and N fertiliser application rate.

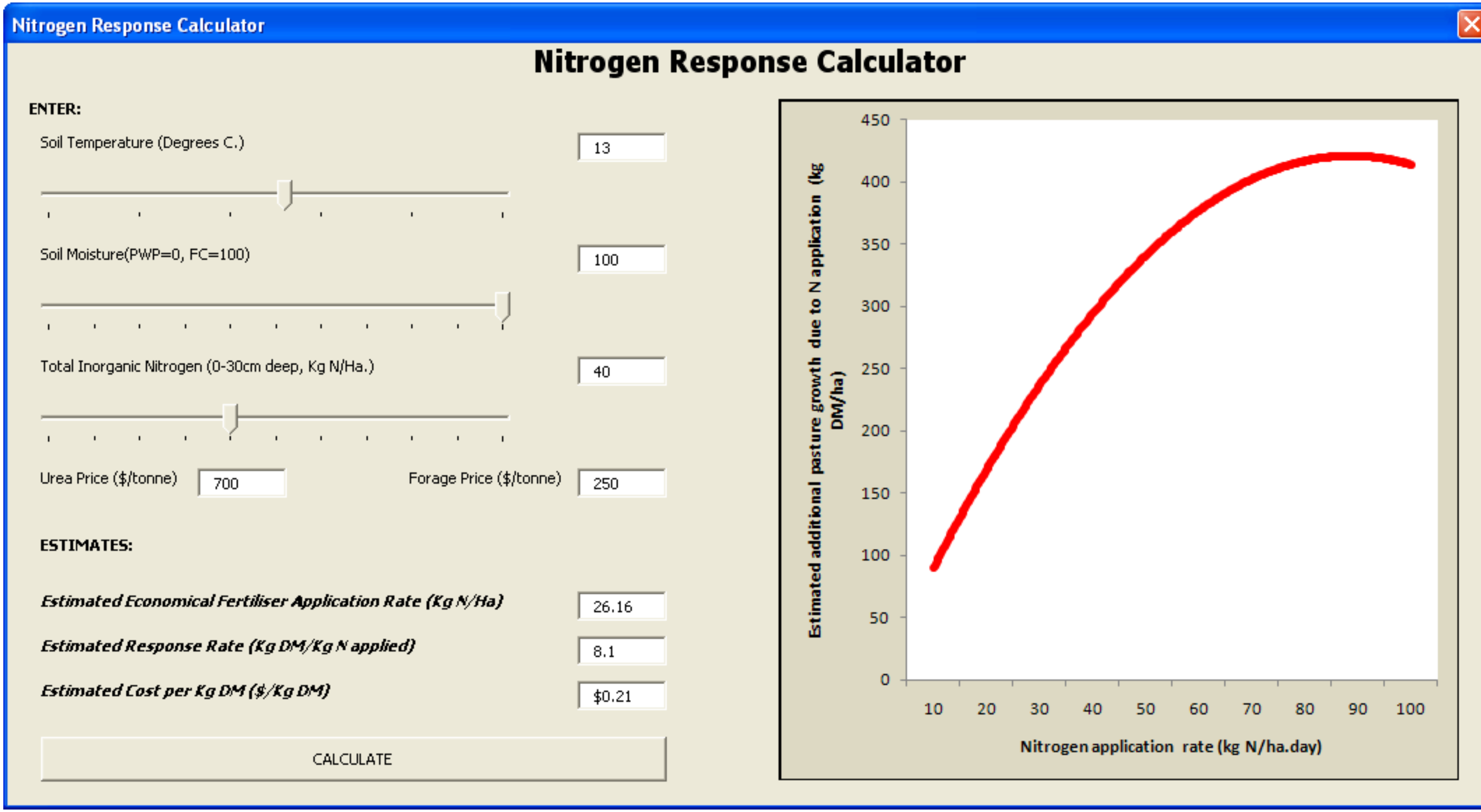
To activate this calculator, the macro setting needs to be enabled. Consult MS Excel help if unsure how to do this .

LAUNCH CALCULATOR

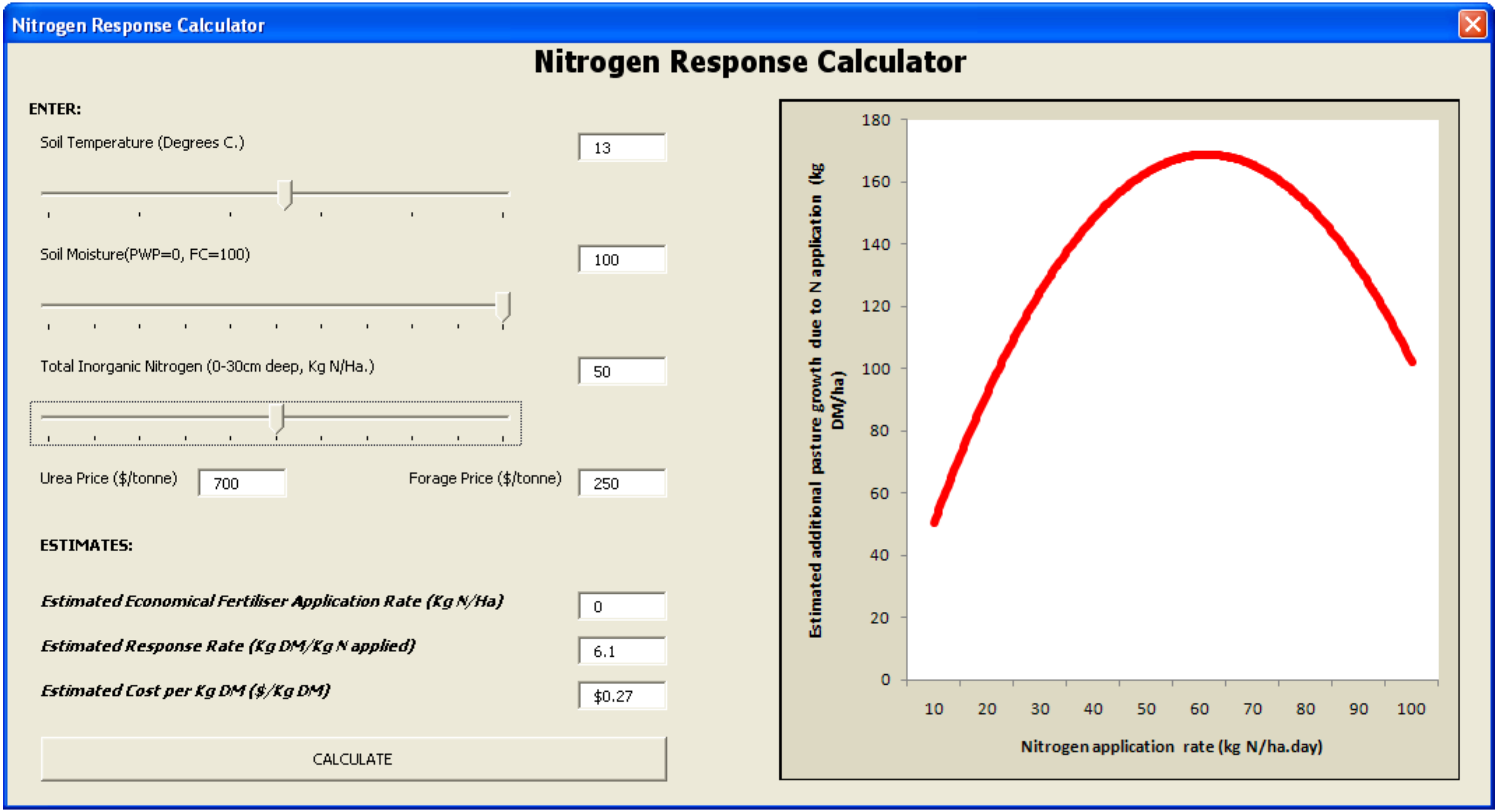
Development tools



Development tools



Development tools



Dairy Nitrogen for Greater Profit

Cameron Gourley

Ivor Awty, Murray Hannah, Kohleth Chia, Bill Malcolm, Kerry Stott, Matt Cox, Oliver Lardner, Jenny Collins, Donna Gibson, Richard Rawnsley, Keith Pemberton, Jeff Kraak, Aaron Gosling, Lee Menhenett, David James, Mark Jago.

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Standardise and improve nitrogen fertiliser decisions

"…..help determine how much N to apply to a particular pasture, at a particular time of the year, in a particular region, that will maximise profitability."

National, simple, relevant, widely accessible, web-based, flexible, instantaneous, ……….

- *Use the best scientific information available*
- *Provide credible economic outcomes*

Source Gourley 2014, Dairy Nitrogen for Greater Profit

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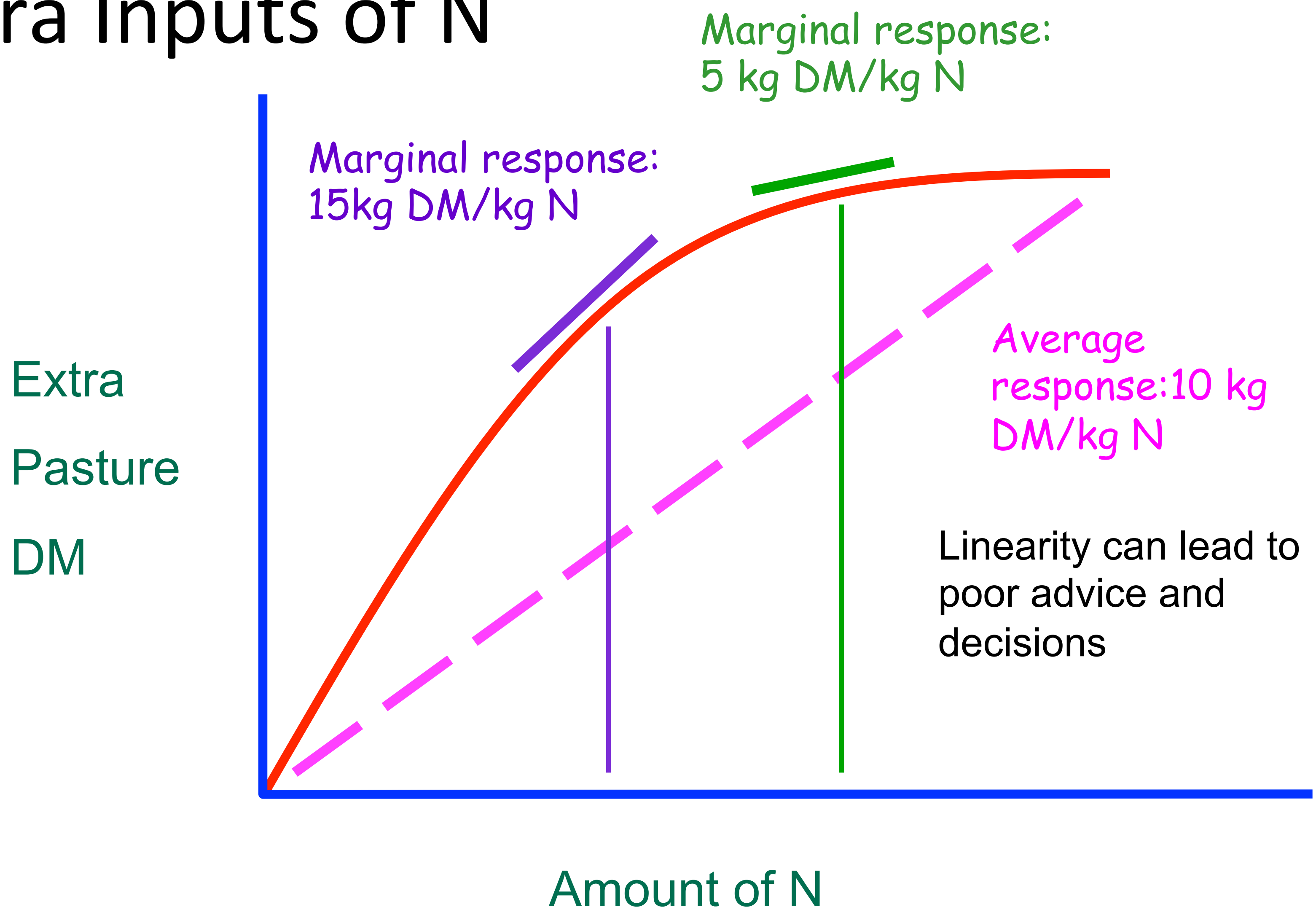
Diminishing DM Responses to Extra Inputs of N



Linearity can lead to poor advice and decisions

Source Malcolm 2014, Dairy Nitrogen for Greater Profit

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Tasks and activities

1. Improve predictive capacity of Pasture DM yield responses to applied N fertiliser
   - Collation of national N fertiliser experiments
   - Detailed meta-analysis of existing data
   - Validation with 'on-farm' N experiments
2. Improve the determination of economic returns from N fertiliser inputs
   - based on estimates of production and profitability
3. Build a web-based tool 'Dairy Nitrogen Fertiliser Advisor'
4. Delivery enhanced information, knowledge and tools to industry

Source Gourley 2014, Dairy Nitrogen for Greater Profit

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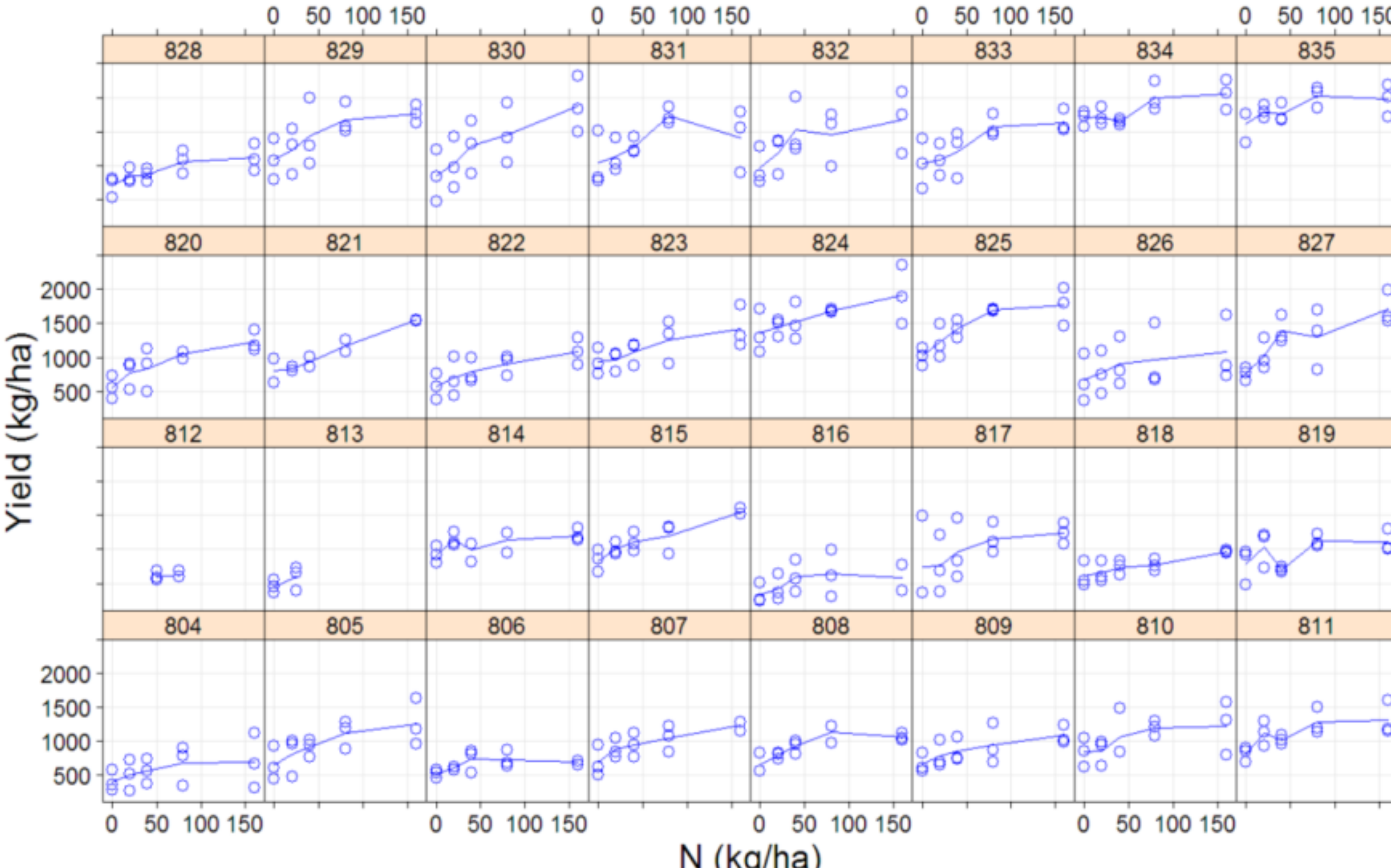
Tasks and activities

5,959 Partitions



Source Gourley 2014, Dairy Nitrogen for Greater Profit

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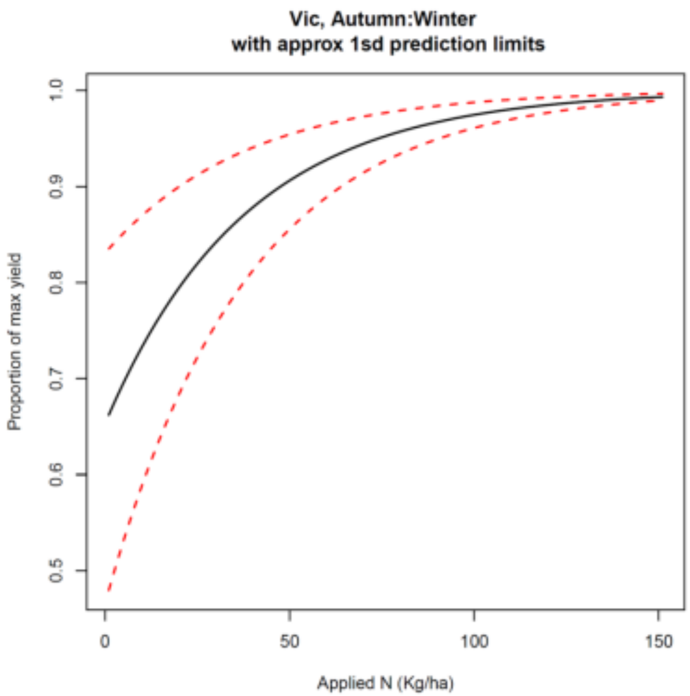
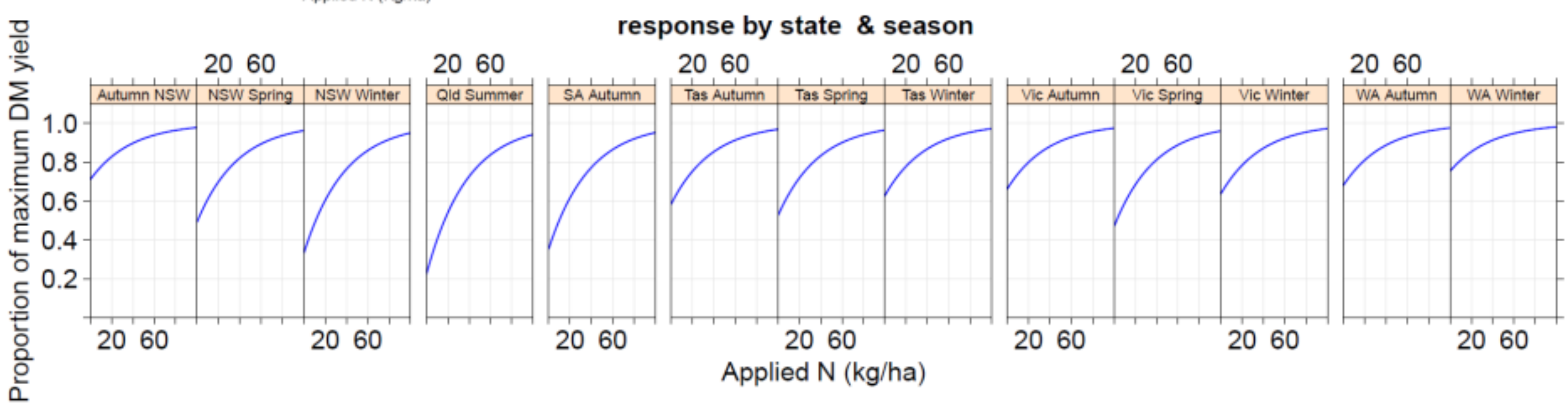
Tasks and activities



	α value (SE)
Scenario:	Non-Residual cut
limiting P	1881 (170)
non-limiting P	2182 (176)

	β value (SE)
Scenario:	Non-Residual cut
NSW, Autumn	1.20 (0.690)
NSW, Spring	0.68 (0.290)
NSW, Winter	0.40 (0.200)
Qld, Summer	0.25 (0.130)
SA, Autumn	0.44 (0.100)
Tas, Autumn	0.88 (0.300)
Tas, Spring	0.74 (0.230)
Tas, Winter	0.99 (0.260)
Vic, Autumn	1.10 (0.064)
Vic, Spring	0.63 (0.320)
Vic, Winter	1.00 (0.200)
WA, Autumn	1.10 (0.310)
WA, Winter	1.40 (0.760)

	λ value (SE)
All scenarios	0.0261 (0.0026)



Source Gourley 2014, Dairy Nitrogen for Greater Profit

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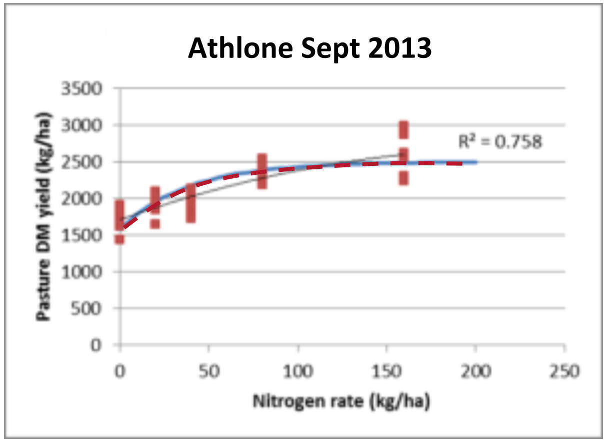
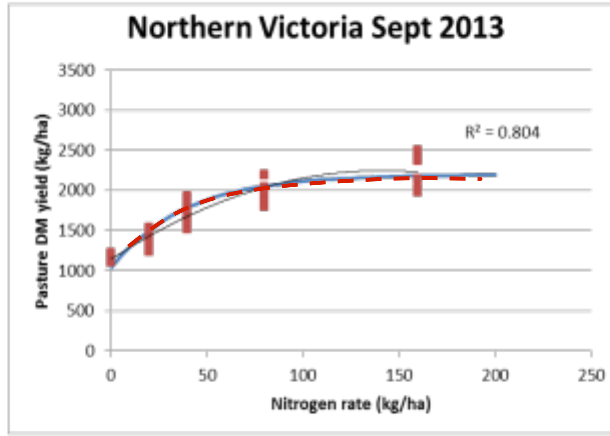
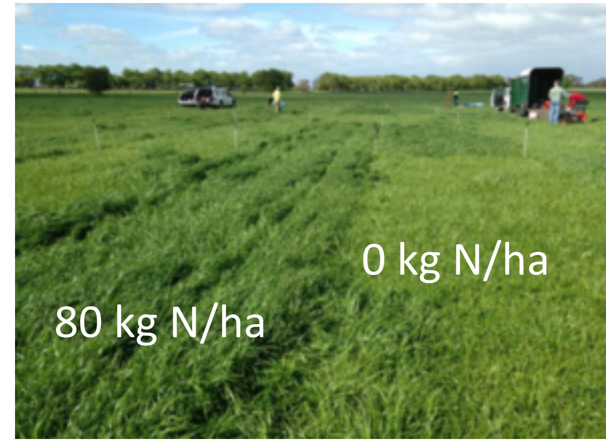
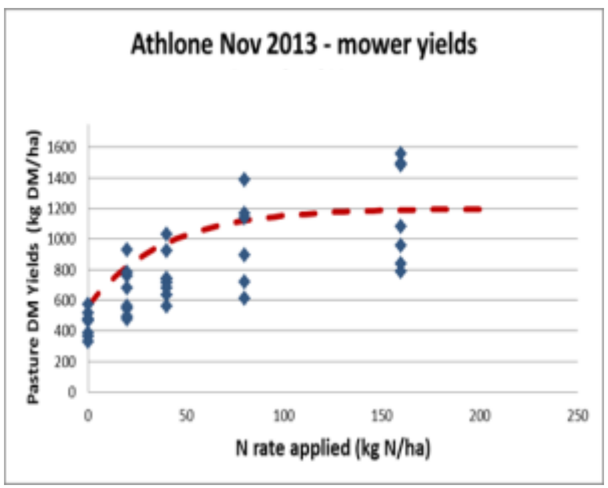
Pasture DM responses to applied urea fertiliser.

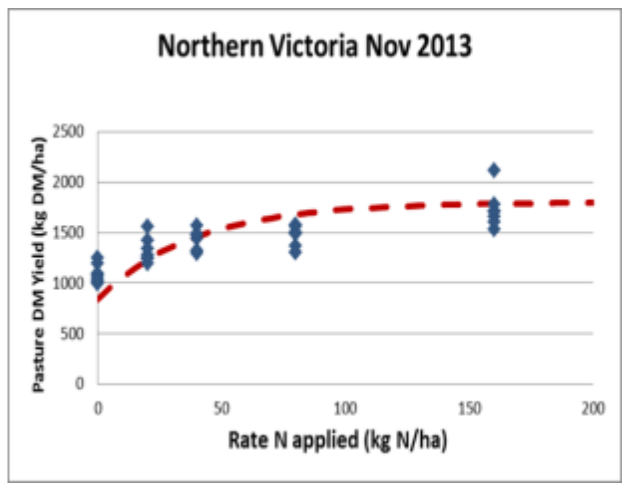
- Red or blue squares are raw DM yield measures with black 'line of best fit'.
- Red curve is independent model prediction from meta-analysis.

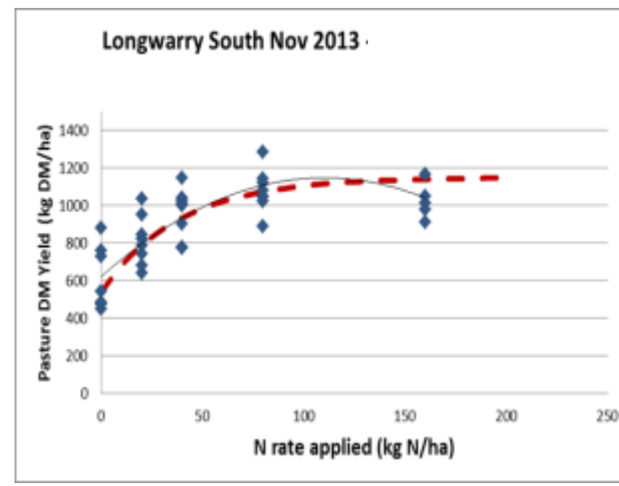












Source Gourley 2014, Dairy Nitrogen for Greater Profit

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Profit maximisation MR=MC

- last unit of input produces enough revenue to just cover the cost of the input
- MR = marginal unit of output (marginal product) multiplied by the price of the output.
- MC = cost of the extra unit of input also expressed as:
  - MP=Px/Py
  - where Px = cost of N Py = price of DM
  - solved for the input x (N fertiliser) to determine the optimum amount of N to use.

Source Malcolm 2014, Dairy Nitrogen for Greater Profit

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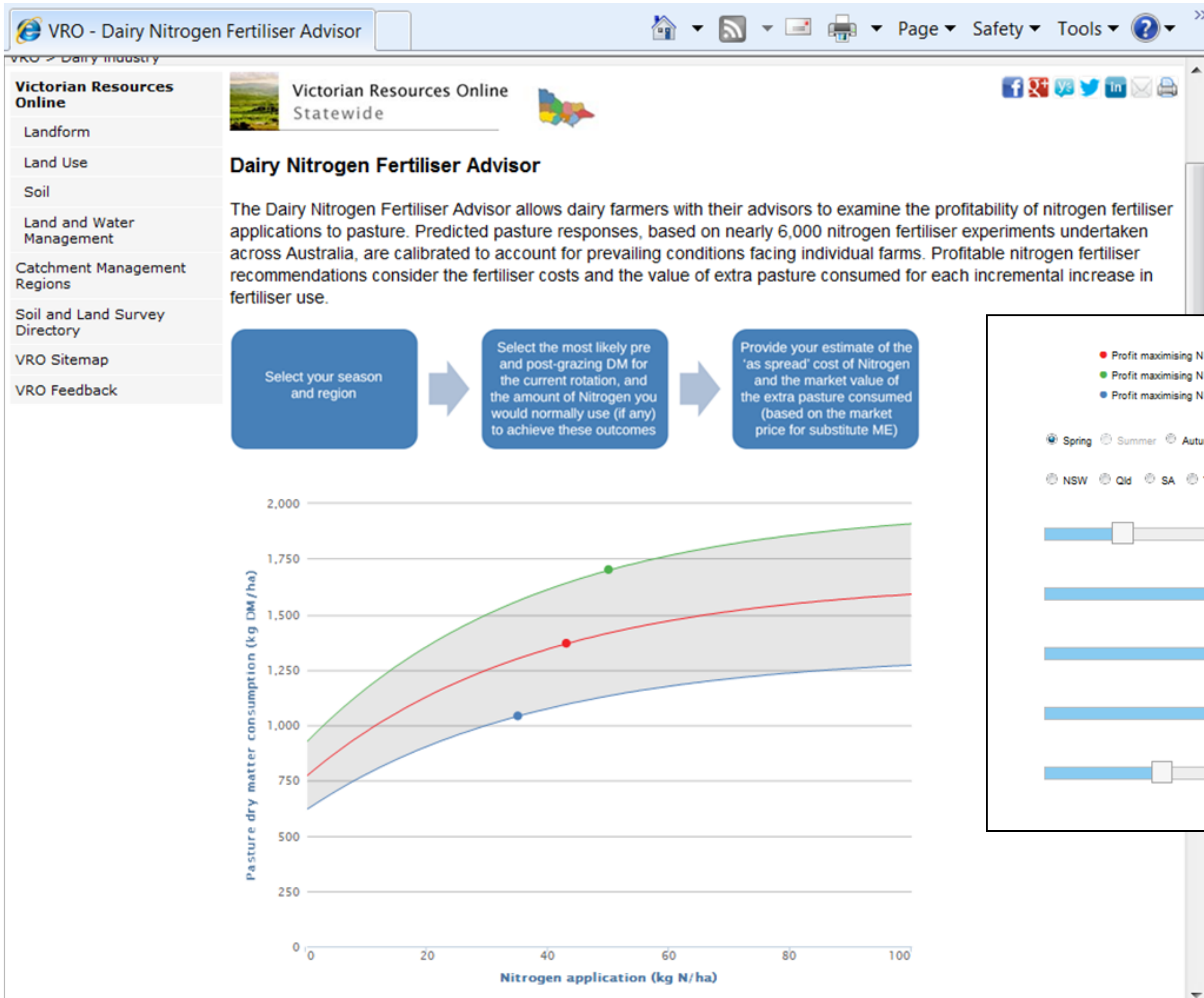
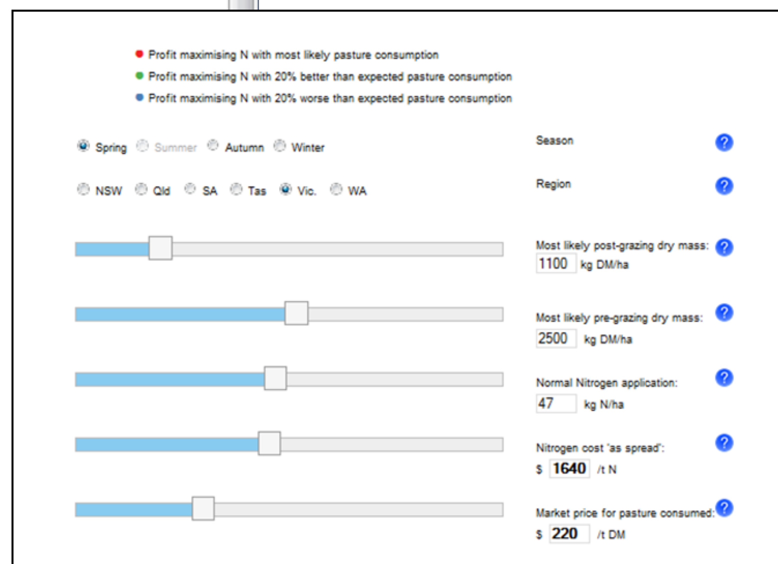
Dairy Nitrogen Fertiliser Advisor

http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/pages/nitrogen-advisor



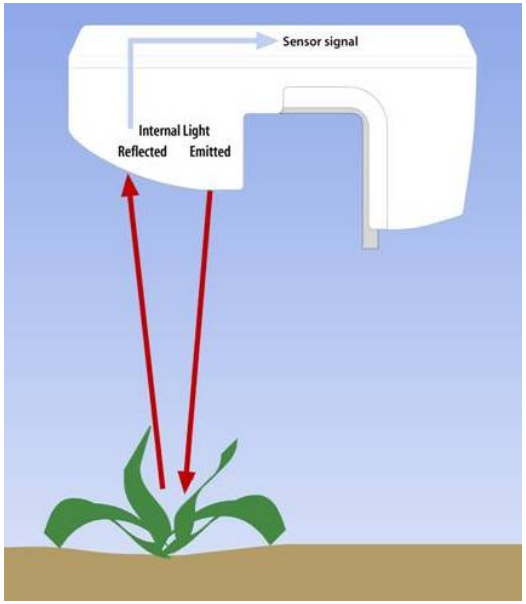


The Smart-N Fertiliser Application System

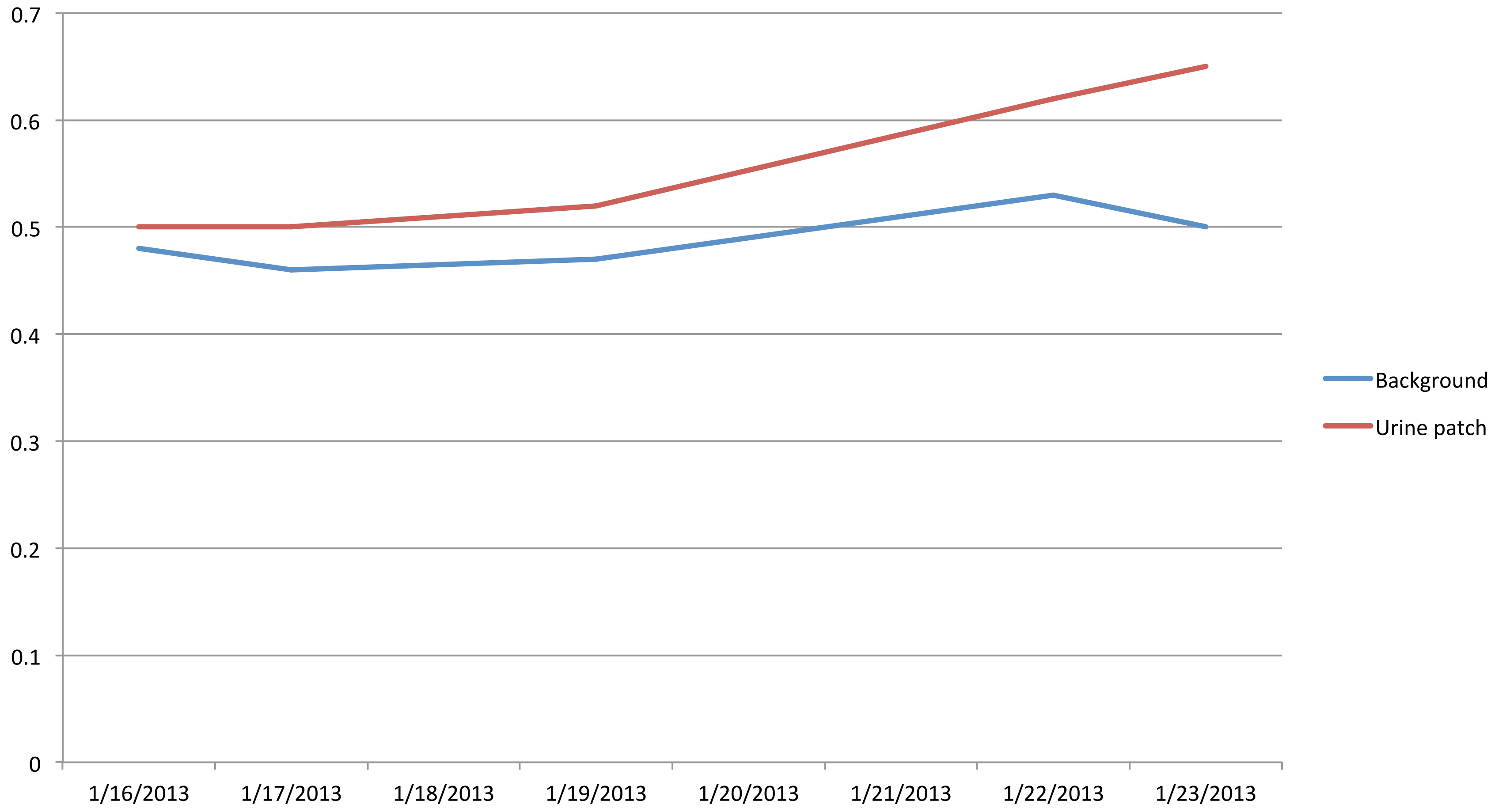
How it works

Sensor

$$\text{NDVI} = \frac{\text{NIR} - \text{VIS}}{\text{NIR} + \text{VIS}}$$

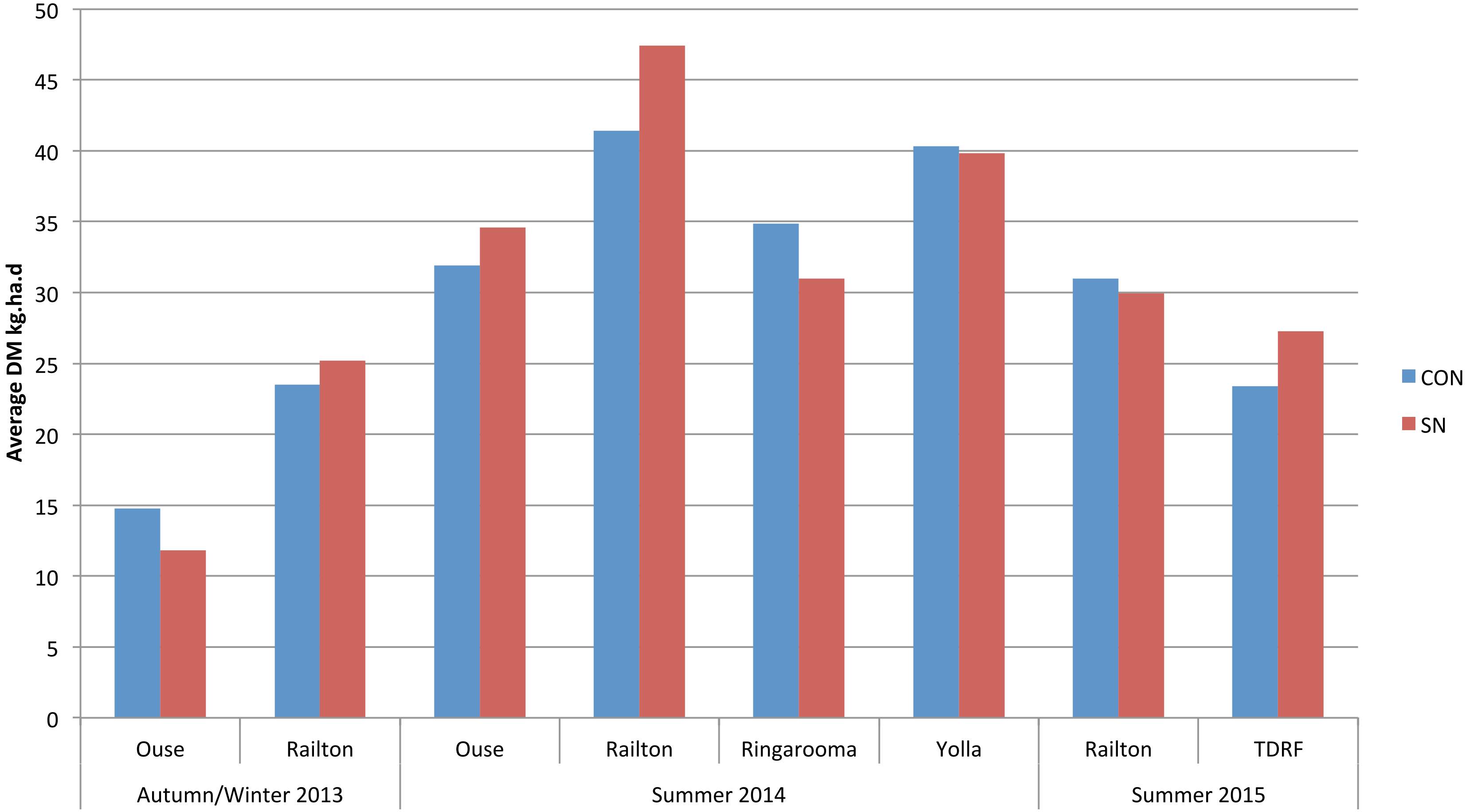


NDVI readings

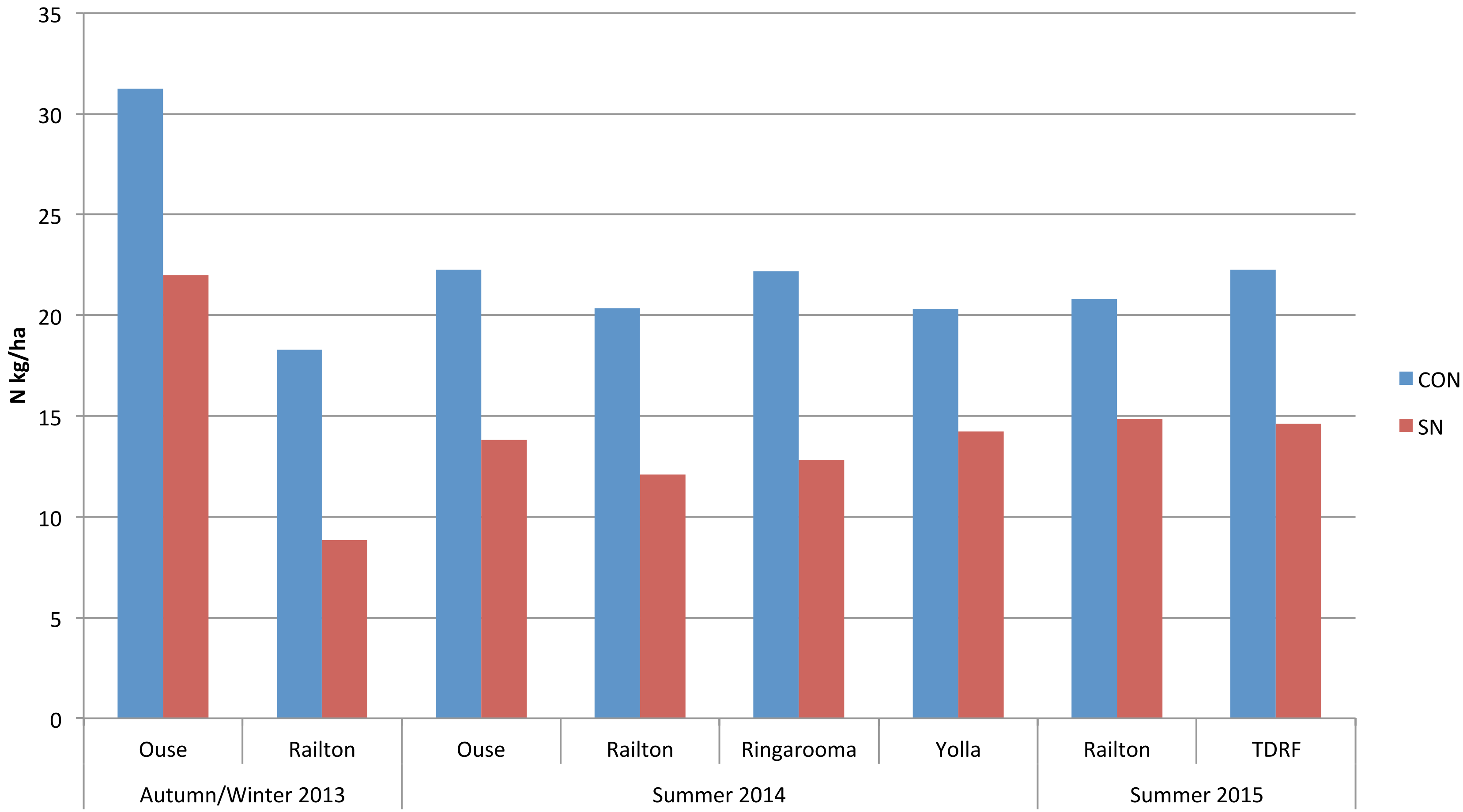


Smart N Boom

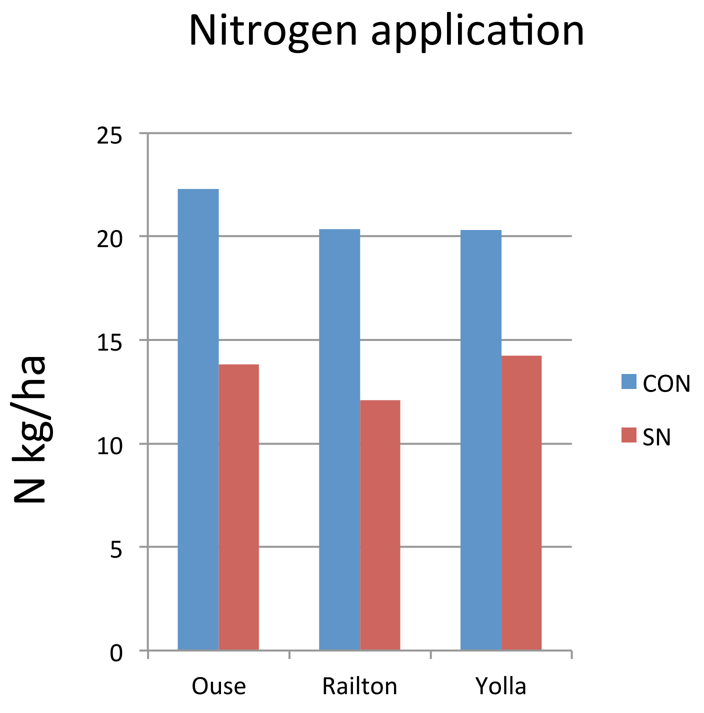
Pasture growth



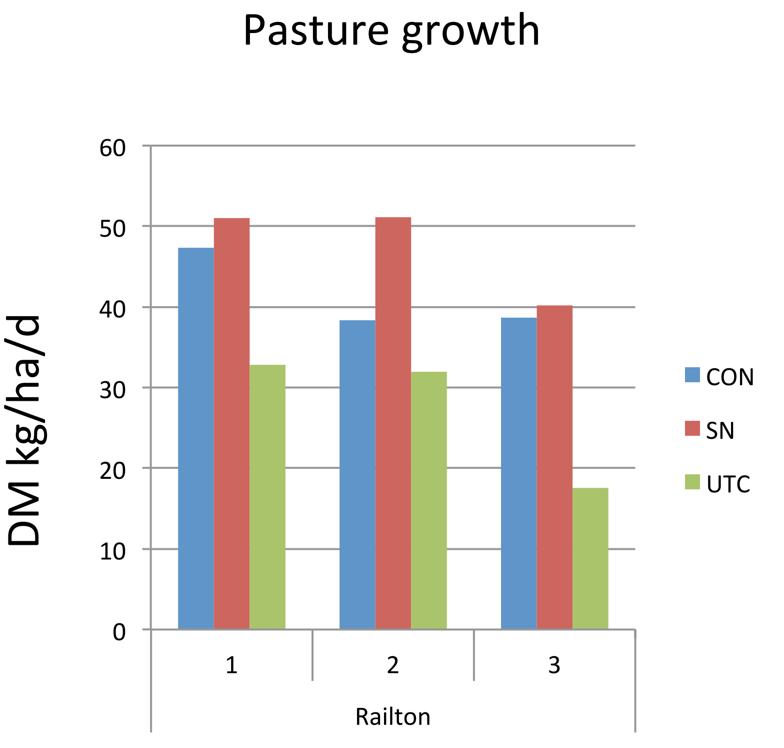
Nitrogen application



Results



Nitrogen application
N kg/ha
25
20
15
10
5
0
Ouse
Railton
Yolla
CON
SN

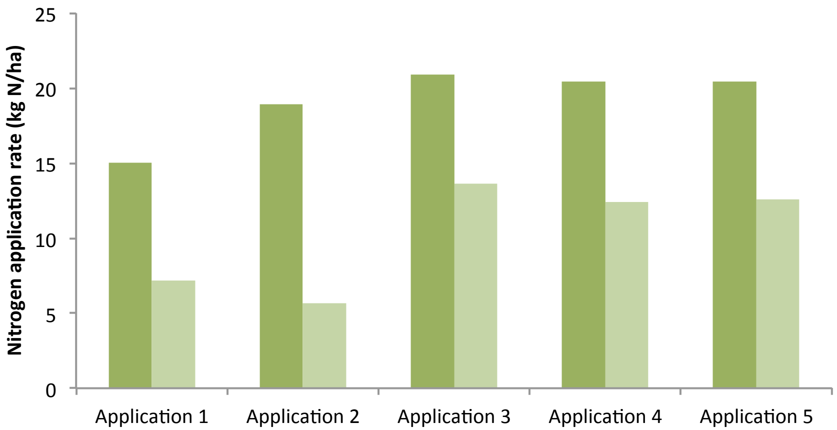


Pasture growth
DM kg/ha/d
60
50
40
30
20
10
0
1
2
3
Railton
CON
SN
UTC

Greenseeker technology

For every Kg of N fertiliser applied have an Emission Factor (EF) of 6.2 kg CO_2-e.

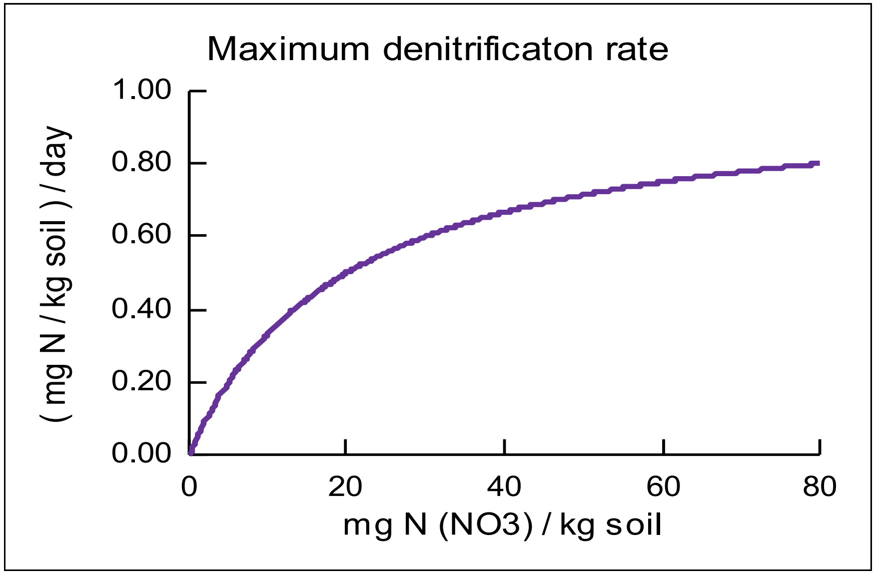
- Direct N_2O losses from denitrification (EF 1.9)
- Indirect N_2O losses from leaching & volatilisation (2.3 EF)
- Embedded emissions in production (EF 2.0)



Source: Action on the Ground project: AOTGR1-124 "Lowering nitrous oxide emissions in intensively grazed pasture systems"

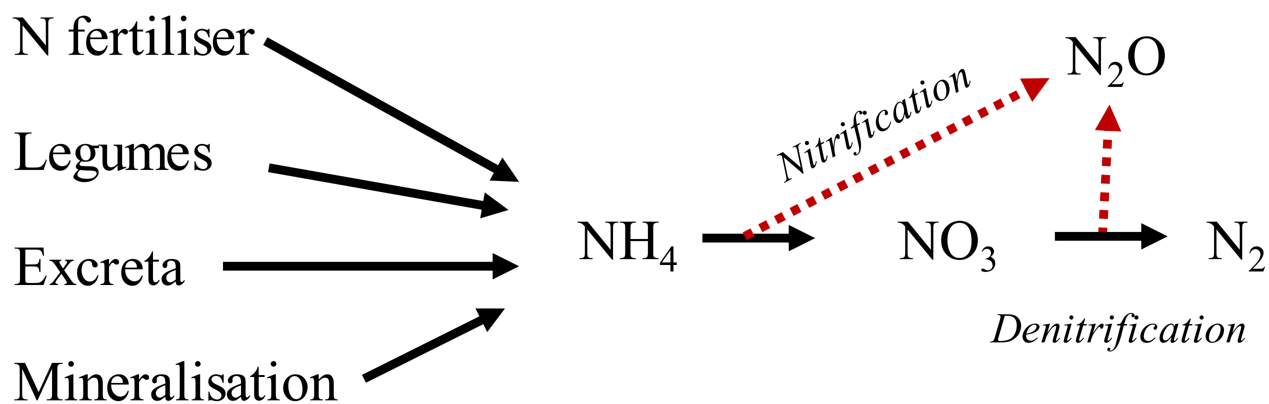
Simulated annual N fertiliser inputs with or without the adoption of the Smart-N™ Greenseeker® technology was 322 and 270 kg N/ha.year, respectively (52 kg N/ha saving). This represents a 16% reduction in N usage.

- N leaching losses decreased from 88.5 to 73.5 kg N/ha.year (15/52 = 29%)
- Simulated average N volatilisation losses decreased from 46.7 to 40.5 kg N/ha.year (6.2/52 = 12%).
- Results consistent with NGGI.
  - The leach fraction and volatilisation fraction are 30 and 10%, respectively.
- Modelling indicates that EF of 1.8 for leaching, 0.5 for volatilisation (2.3 for indirect N_2O losses) can be applied to the Smart-N™ Greenseeker® technology.
- However there was little change in denitrification rate. Why?



Nitrous oxide

- Global warming ~300 x CO_2
- Denitrification
  - Warm, water-logged soils
  - Excess NO_3 in soil
- Inefficient use of nitrogen
  - Ruminants excrete 75 to 95% of N intake
  - >60% lost

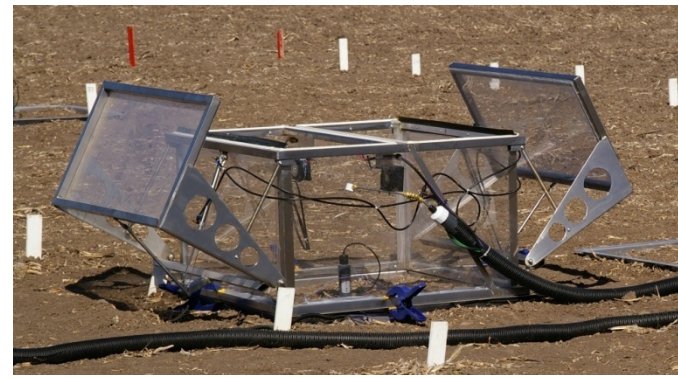


Source Eckard 2010

Nitrous oxide

Measuring nitrous oxide

Automatic Chambers



Micromet system

Source Eckard 2010

Nitrous oxide

- Approaches to reducing N_2O emissions
  - Nitrogen Fertiliser
    - Rate, source, timing, placement
    - Formulation
  - Water management
    - Drainage, irrigation
  - Soil Management
    - Reduced tillage
  - Animal Management
    - Stocking density, diet, hot spots
- Short term mitigation
  - Feed
    - Balancing ME:CP
    - Tannins
  - Inhibitors
    - Enhanced efficiency fertilisers (EEFs) containing the N inhibitors
- Longer term mitigation options
  - Breeding
    - Improved animal FCE
    - Improvement plant ME:CP

Source Eckard 2010

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Thank You

Questions?

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Tasmania
Explore the possibilities