A Calibrated Model for Pasture Yield Response to Nitrogen Fertiliser

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Trend in dairy nitrogen fertiliser use

Sources: ABARE, ABS, DA
An economic and environmental question

How much N to apply?

... so that the last kilogram

- Adds to profit
- Has high NUE
Pasture yield vs N applied?

- Require a relationship
  - a realistic model
- How?
  - A bio-physical model?
  - An empirical model?
  - Data?
Better Fertiliser Decisions database

- 920 trials with applied N
- 5,959 partitions (same site, date, treatments; a curve)
- 19,915 rows of data
- 64 data columns
  - Pasture yield measure
  - N applied
  - 62 columns of meta data (demographic, experimental, environmental)
Rates of N applied within trials

• How many rates in each trial?
  – 150 trials had at least 3 rates

<table>
<thead>
<tr>
<th># N levels</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>16</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td># Trials</td>
<td>19</td>
<td>751</td>
<td>7</td>
<td>9</td>
<td>84</td>
<td>32</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>14</td>
</tr>
</tbody>
</table>

• Largest N rate in each trial?
  – 117 trials had a max rate greater than 80 kg N/ha

<table>
<thead>
<tr>
<th>N (kg/ha)</th>
<th>&lt;20</th>
<th>20-40</th>
<th>40-60</th>
<th>60-80</th>
<th>80-100</th>
<th>&gt;100</th>
</tr>
</thead>
<tbody>
<tr>
<td># Trials</td>
<td>8</td>
<td>11</td>
<td>62</td>
<td>722</td>
<td>29</td>
<td>88</td>
</tr>
</tbody>
</table>
## Number of rows of data by State and Season

<table>
<thead>
<tr>
<th>State</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW</td>
<td>83</td>
<td></td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Qld</td>
<td></td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SA</td>
<td></td>
<td></td>
<td>352</td>
<td></td>
</tr>
<tr>
<td>Tas</td>
<td>128</td>
<td>120</td>
<td>427</td>
<td></td>
</tr>
<tr>
<td>Vic</td>
<td>42</td>
<td>11,735</td>
<td>655</td>
<td></td>
</tr>
<tr>
<td>WA</td>
<td>396</td>
<td></td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>
The first 32 (of 5,959) partitions
Model development

- Mitscherlich, \( y = \alpha (1 - e^{-\lambda x - \beta}) \)
  - Simple
    - Requires few points of support
    - Can be expanded
  - Widely used
    - Often adequate
    - Interpretable parameters
Model development strategy

• Exploratory phase:
  – Fit a Mitscherlich curve to each partition
    • Graph $\hat{\alpha}, \hat{\beta}, \hat{\lambda}$ against meta data.
    • Separate models for $\alpha, \beta, \lambda$

• Formal modelling phase:
  – Pool information
  – Expand Mitscherlich to non-linear mixed model
  – Test meta-data terms
Expanded model (final model)

\[ y = \alpha (1 - e^{-\beta - \lambda N}) + \varepsilon \]

where,
\[
\alpha = \mu_\alpha + \tau_\alpha + \varphi_{P,\text{check}} + L_\alpha + Pa_\alpha
\]
\[
\beta = \exp(\mu_\beta + \tau_\beta + \theta_{\text{state.season}} + L_\beta + Pa_\beta)
\]
\[
\lambda = \exp(\nu)
\]

Fitted using \texttt{nlme()}, R
The first 32 (of 5,959) partitions, fitted model
Max yield $\alpha$ sub-model - “surprises”

- Residual harvests had greater max yield than primary harvests
- Yield decreased with growth-time
- Large SDs for max yield between sites, & between partitions,

Sub-model for $\alpha$ (max yield) is not useful.

(Max yield a matter of harvest protocol)

How does applied N affect the proportion of max yield?
Proportion of yield due to applied fertiliser N

Proportion of max DM = $1 - e^{-\beta - \lambda N}$

$\beta = \exp(\mu + \tau + \theta_{\text{state.season}} + L_{\beta} + Pa_{\beta})$
Validation

- 4 new data sets
  - 4 dates, 3 sites
- Proportional response model
  - Scaled to actual max DM yield
- Slope is critical
Conclusions

- A model for DM yield response to applied N
- Calibrated to 40 years of experimental data
- Expressed as a proportional response
- To be scaled to a maximum DM yield (target)
- Further validation/recalibration
- Assist fertiliser decision making
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