Developing a decision support tool for optimising organo-mineral fertilisation strategies and improving nitrogen use efficiency

Johannes Biala[1], Daniele De Rosa[1], David Rowlings[1], Peter Grace[1]

[1]Institute for Future Environments, Queensland University of Technology, Brisbane, QLD 4000, Australia, https://www.qut.edu.au/research/research-projects/greenhouse-gas-research, j.biala@qut.edu.au

Abstract
Farmers are under pressure to operate more efficiently and reduce negative environmental impacts while maintaining or increasing production. Accurate accounting for nutrients supplied with organic soil amendments and appropriate reduction of mineral fertiliser inputs provides an easy way of achieving these goals. This paper outlines what is necessary to develop a decision support tool for optimising fertilisation strategies that utilise both organic and synthetic nutrient sources and improve nitrogen use efficiency. Novel aspects of the proposed calculator are that (i) it integrates organic and synthetic N sources, (ii) it caters for repeat applications and accounts for long-term nutrient release, (iii) it incorporates a paddock-scale nutrient budget, and (iv) it has scope for future expansion to include changes in soil properties brought about by the use of organic soil amendments.

Key Words
Manure, organic soil amendments, nutrient budget

Introduction

Australia's intensive animal industries generate well in excess of three million tonne (Mt) of manure annually, including 1.3 Mt feedlot manure, 1.1 Mt poultry litter, 0.47 Mt layer chicken manure and 0.32 Mt piggery solids (GRDC, 2010). These animal manures plus collected dairy manure and effluent contain approximately 90,000 t of nitrogen (N), 28,000 t of phosphorous (P) and 38,000 t of potassium (K), representing about 10% of the amount of N and P consumed in mineral fertilisers in Australia and around 30% of K (FIFA 2010). Most animal manures are used as organic soil amendments to enhance soil properties and supply plant nutrients. While some farmers might account for P and K contributions from manure products and reduce mineral fertiliser inputs accordingly, this is less likely for N, trace elements and liming effects. As N content and availability is not well reflected in prices for manure products, little effort is made to minimise N losses during manure storage, processing (composting) and post application. Current research aimed at reducing N losses from the manure supply chain, e.g. during composting (Biala et al. 2016), by using composted rather than raw manures (De Rosa et al. 2016) or by applying sorber minerals (Pratt et al. 2016), is futile unless farmers account appropriately for N inputs from organic soil amendments, and reduce the use of mineral N fertiliser accordingly. The pressure on farmers to improve N use efficiency and reduce N losses is ever increasing, which is particularly evident where N losses have direct negative effects, such as in the Great Barrier Reef Catchments. The Reef 2050 Long-Term Sustainability Plan calls for an 80% reduction in dissolved inorganic N flowing out to the reef by 2025 and 90 % of agricultural land in priority areas being managed using best management practice systems by 2018 (Commonwealth of Australia 2015). Options that are currently discussed to achieve these goals are N input caps (widely used in Europe) and N trading schemes (Smart et al. 2016).

Regardless whether farmers operate in Great Barrier Reef Catchments or not, and if they face N input caps or N trading schemes, all farmers in Australia that utilise organic soil amendments (e.g. manure, biosolids, millmud, compost) need a user-friendly and integrated tool to account for plant nutrients supplied by organic soil amendments to reduce mineral fertiliser inputs accordingly, simply to make their farming operation more nutrient efficient and more profitable.

This paper will outline the steps necessary to develop such a tool, how its use by farmers can be facilitated, the benefits it can deliver, and the potential for expanding and enhancing the tool in the future.

Materials and Methods

Basics

Models and algorithms defining mineralisation and nutrient release rates over time following the repeated use of organic soil amendments will be based on outcomes of recent large Australian R&D programs (Filling the Research Gap, Action on the Ground) and associated datasets available for example via the N_2O Network (http://www.n2o.net.au/), other relevant Australian and overseas research, and data supporting existing nutrient benefit calculators for manures (e.g. MANNER–NPK, Planet Nutrient Management 2016) and composts (e.g. Compost Benefit Calculator, AORA 2012). The following key information has to be available to allow users of the decision support tool to estimate immediate and gradual supply of macro and micro nutrients following the use of organic soil amendments and also to reduce mineral fertiliser inputs:

- (i) product characteristics of organic soil amendments,
- (ii) soil type and chemical soil properties
- (iii) environmental conditions and rainfall / irrigation predictions
- (iv) cropping sequence
- (v) yield expectations and nutrient requirements
- (vi) organo-mineral fertilisation strategy (type, rate, timing)

While the software underpinning the decision support tool will provide the 'black box', including long-term environmental and climatic conditions, users of organic soil amendments will have to provide the above information, most of which farmers will have at their fingertips. Analytical results will provide product characteristics for organic soil amendments. However, a user-friendly tool will require a uniform laboratory reporting format and determination of bulk density for the analysed product.

Conceptual model for repeat applications

Farmers using organic soil amendments tend to apply these products repeatedly, often annually. This means that both short- and long-term N supply has to be taken into account, as well as cumulative effects. Further aspects that need to be considered are (i) variability of seasonal N supply in cropping system with multiple crops per year, and (ii) increasing nitrogen use efficiency associated with long-term repeated use of organic soil amendments (>6-9 years) (Haber et al. 2008). Figure 1 shows a conceptual model for integrated nitrogen supply from organic and mineral sources in an intensive vegetable production system.

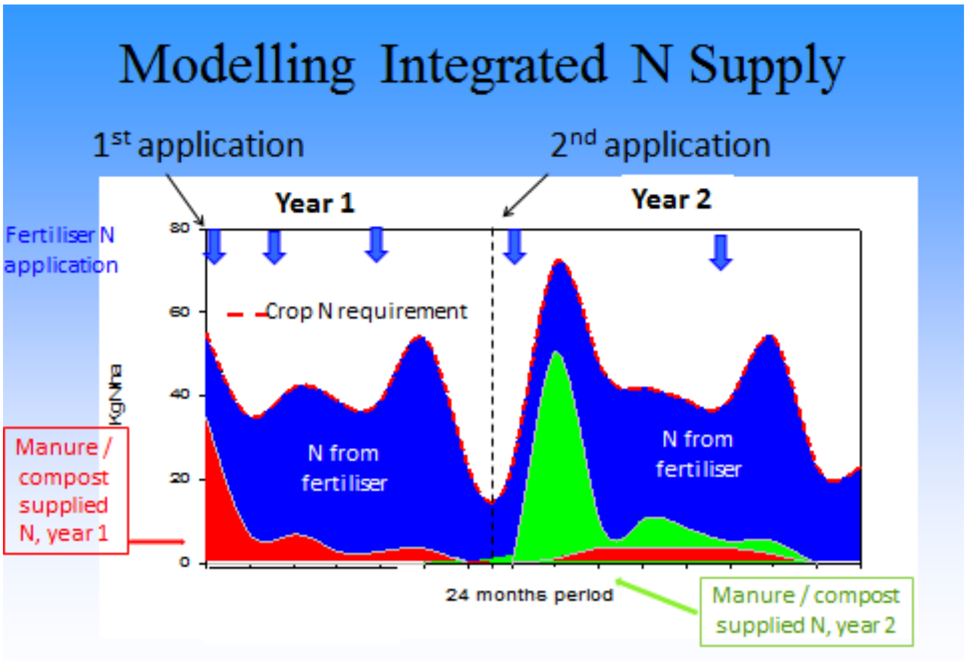

Figure 1. Conceptual model for integrated nitrogen supply from organic soil amendments and mineral fertiliser in intensive vegetable production with multiple crops per year

Nutrient budgeting

This organic amendment decision support tool will encompass a paddock-scale nutrient budget component for field cropping, accounting not only for N, but also P, K, Ca, Mg, and key trace elements. Integration of the nutrient budget into the software package will allow farmers to select the optimum combination of organic soil amendments and mineral fertilisers, enabling them to achieve high nitrogen / nutrient use efficiency and prevent the over- or undersupply of N, P or K.

Example
A recent trial in an intensive vegetable production system (seven cash crops in 2.5 years) showed that accounting for available and mineralised N supplied from organic amendments (raw and composted feedlot and chicken (layer) manure) led to a reduction of synthetic N inputs (770 kg N ha^{-1} during 2.5 years) by between 25% and 38% without affecting yield when compared to standard fertilising practices (Rowlings et al. 2016).

Facilitating Use of the Tool
Although all animal manures generated in Australia, plus various other products are used as organic soil amendments, farmers in general are not very knowledgeable when it comes to choosing and using organic soil amendments and determining the benefits they can and cannot derive from them (Biala and Milgate 2014, Wright et al. 2016). This decision support tool will allow farmers to recognise nutrient contributions from organic soil amendments towards meeting crop nutrient requirements and to reduce mineral fertiliser inputs accordingly, allowing them to offset some of the additional costs of purchasing and spreading organic soil amendments. These financial benefits will drive demand for the tool by farmers who use organic soil amendments.

For the up-take to be wide-spread, the interface for this decision support tool will have to be distinctly user-friendly and exceed the performance of existing tools. The key advantages of our calculator will be (i) the integration of organic and mineral nutrient sources and (ii) outputs in the form of paddock-scale nutrient budgets, both of which will make the life of farmers easier.

The organic amendment decision support tool, which might be web-based, will be freely available for all interested users, and it is envisaged that its use will be promoted not only by suppliers of organic soil amendments, but also by farming industry groups, government departments and NRM organisations.

Future Options
Once developed and the structures and platforms are in place, the decision support tool for optimising organo-mineral fertilisation strategies and improving nitrogen use efficiency will need to be updated and improved regularly to incorporate new and additional information for existing systems, or new information for example for new products or new crops. Furthermore, in the future it is possible to expand the tool to

(i) account not only for nutrient benefits but also for carbon inputs and their effects (for example) on cation exchange and water holding capacity,
(ii) include farm animals, and
(iii) collate paddock-scale nutrient budgets into farm-scale budgets.

Conclusions
Good management of synthetic fertiliser and nutrients in organic soil amendments is essential for farmers to grow food and fibres that people want to buy, whilst minimising environmental harm. The proposed decision support tool for optimising organo-mineral fertilisation strategies will assist in achieving this goal. Proper accounting for nutrients supplied in organic soil amendments combined with the respective reduction of mineral N fertiliser use is a sure way of making organic soil amendment products more valuable, of reducing farm input costs, of improving nitrogen use efficiency, and of reducing undesirable N loss to the environment.

References
AORA [Australian Organic Recycling Association] (2012). Launch of new app – Compost Benefits Calculator. http://www.aora.org.au/index.php?id=39. Accessed 27 June 2016.

Biala J, Lovrick N, Rowlings D, Grace P (2016). Greenhouse-gas emissions from stockpiled and composted dairy-manure residues and consideration of associated emission factors. Animal Production Science 56, 1432-1441.

Biala J and Milgate M (2014). Grower expectations and experiences with the use of organic mulches and soil amendments in the horticultural industry in Queensland, Australia, 473 – 479 in: Acta Horticulturae 1018, Proceedings of the First International Symposium on Organic Matter Management and Compost Use in Horticulture, 4 – 7 April 2011, Adelaide

Commonwealth of Australia (2015). Reef 2050 Long-Term Sustainability Plan. http://www.environment.gov.au/marine/gbr/publications/reef-2050-long-term-sustainability-plan. Accessed 27 June 2016.

De Rosa D, Rowlings DW, Biala J, Scheer C, Basso B, Mc Gree J, Grace PR (2016). Effect of organic and mineral N fertilizers on N_2O emissions from an intensive vegetable rotation. Biology and Fertility of Soils 52, 895-908.

Ryan T (2010). The Australian fertilizer industry -- values and issues. Australian Fertilizer Industry Conference, Gold Coast, Australia. (Fertilizer Industry Association of Australia, Canberra) 97 pp. https://www.iama.org.au/sites/default/files/Australian%20Fertilizer%20Industry%20Value%20and%20Issues%20August%202010.pdf. Accessed 25 April 2016.

GRDC [Grains Research and Development Corporation] (2010). Using recycled organics and manures in grain cropping systems. http://grdc.com.au/Resources/Factsheets/2010/05/Recycled-Organics-Fertiliser. Accessed 25 April 2016.

Haber N, Kluge R, Deller B, Flaig H, Schulz E, Reinhold J (2008). Nachhaltige Kompostanwendung in der Landwirtschaft (*Sustainable use of compost in agriculture*). Landwirtschaftliches Technologiezentrum Augustenberg, Karlsruhe, Germany.

Planet Nutrient Management (2016). MANNER-NPK [MANure Nitrogen Evaluation Routine]. http://www.planet4farmers.co.uk/Manner. Accessed 27 June 2016.

Pratt C, Redding M, Hill J, Brown G, Westermann M (2016). Clays can decrease gaseous nutrient losses from soil-applied livestock manures. Journal of Environmental Quality 45, 638-645.

Rowlings D, Biala J, De Rosa D (2016). Composting as a means of minimising greenhouse gas emissions from the manure supply chain. Final Technical Report to the Department of Agriculture and Water Resources, Canberra (unpublished)

Smart J, Volders A, Fleming C, Hasan S (2016). Could 'nitrogen trading' help the Great Barrier Reef? The Conversation 16. 6. 2016. https://theconversation.com/could-nitrogen-trading-help-the-great-barrier-reef-60930. Accessed 27 June 2016.

Wright B, Curtis J, Boulet M (2016). Knowledge, experiences and expectations of commercial compost products: Perceptions from dairy farmers and their advisors. Report for Sustainability Victoria, Melbourne (unpublished)