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INTENSIFICATION, NITROGEN USE AND PERFORMANCE INDICATORS FOR AUSTRALIAN DAIRY PRODUCTION

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Abstract

Improved nitrogen (N) utilisation is critical to profitable and sustainable milk production. The determination of a whole-farm N balance (WFNB) can provide a number of N recovery indicators and is commonly used as a nutrient management tool internationally. We used the WFNB approach to evaluate N recovery for the entire Australian dairy industry over a 22 year time period and identified key changes in farm characteristics and management. A long-term trend in declining N recovery was determined for all indicators due to the increasing use of imported feed and fertiliser N associated with ongoing industry intensification. We suggest that in addition to farm-scale WFNB determination, simplified and standardised indices that specifically target key N fluxes within a farm, would further help improve on-farm N management decisions and establish appropriate industry benchmarks.

Key Words

Whole-farm nitrogen balance; nitrogen use efficiency; milk production; grazing-based dairy systems

Introduction

Continued growth in global food production will require further intensification and greater inputs of fertilisers, energy and water (Fuglie 2012). However, the low utilisation of nutrients in many agricultural systems creates an additional challenge with nutrient excesses and environmental degradation of land and water ecosystems and the atmosphere (Sutton *et al.* 2013). This is particularly the case for intensifying dairy production systems where nutrient fluxes may be large and nutrient use efficiency relatively low at the whole-farm level (Jarvis *et al.* 2011).

Accordingly, the development and implementation of tools and policies that address nutrient imbalances before they become extreme are essential for the long-term sustainability of dairy farming (Cela *et al.* 2014). An internationally recognised and commonly use approach is the determination of WFNB (Oenema *et al.* 2003; Gourley *et al.* 2007; Soberon *et al.* 2013), usually determined over a 12 month period, as it is deemed to be simple to calculate, relies on farm data that are readily available and the information generated is easy to communicate to farmers and policy makers.

Whole-farm nutrient balances relay on determining total nutrients imported and total nutrients exported, generally calculated at the farm scale. The key outputs from undertaking a WFNB include the net farm nutrient surplus (the difference between total nutrients imported and those exported from the farm), nutrient use efficiency (the ratio of total nutrient output and nutrient input) and productivity surplus (net farm nutrient surplus divided by the quantity of agricultural product) (Schroder *et al.* 2003; Stott and Gourley 2016), all of which are increasingly recognised as environmental indicators (Jarvis *et al.* 2011). However, a short-coming of these whole-farm N indicators is the lack of guidance they provide to farmers and advisors about opportunities within the current farming system for improved N management practices (Gourley *et al.* 2007).

This paper discusses the benefits of determining N use, and WFNB recovery indicators, using long-term data (1990-2012) from the Australian grazing-based dairy industry. We also identify the key changes in farm characteristics and management associated with dairy industry intensification and propose some farm-based N management indicators which provide guidance for enhancing within-farm N utilization and reducing N emissions.

Methods

The long-term N balance calculations for the Australian dairy industry followed a commonly used farm-scale N balance approach which has been modified to suit Australian dairy farm operations (Gourley *et al.* 2012a) and utilised a nutrient balance tool developed in MS Excel. Briefly, determining the whole-farm N recovery metrics involved quantifying total N inputs and outputs for the Australian 'industry-average' dairy farm. These inputs and outputs included the N embodied in various forms of purchased feed (i.e. fodder, concentrates, grains and by-products) and fertilisers, milk sales and animal purchases and sales. Inputs from N fixation and atmospheric deposition were also included as described by Gourley *et al.* (2012a). Population estimates and average annual per farm data on farm size, herd size and dynamics, and the mass of key N inputs and N outputs were sourced from the Australian Dairy Industry Survey (ADIS) which is conducted on an annual basis by the Australian Bureau of Agriculture and Resource Economics (ABARES) as described by Stott and Gourley (2016).

Results and discussion

On-going intensification in dairy production at both the national and state level has led to fewer and larger dairy farms, with increased stocking rates, reliance on imported feed, nitrogen fertiliser use and milk production per cow and per ha. Individual sources of N inputs, outputs and N recovery measures for an 'industry average' dairy farm Australia-wide for selected years 1990, 2000 and 2012, reflect the ongoing intensification of grazing-based dairy production (Table 1). Over this 22 year period, N inputs always exceeded outputs, with inputs growing at a faster rate. N inputs on the average dairy farm increased from 91 to 214 kg N ha^{-1} and grew at an annualised rate of around 4.0%, while N outputs increased from 36 to 57 kg N ha^{-1} at an annualised rate of around 2.0%. The major contributor to total N inputs was bought-in feed, followed by N fertiliser. Milk production consistently made up the bulk (about 90%) of total N outputs.

Table 1. Nitrogen inputs, exports and recovery measures for the industry average Australian dairy farm.

N source	Units	1990[a]	2000	2012
N Inputs (average per farm)	kg N ha^{-1}			
Cattle		1	1	1
Forage		10	24	31
Concentrates		24	54	81
Fertiliser		18	39	71
Legume N inputs		31	27	26
Atmosphere		6	6	5
N input total		91	151	214
N Outputs (average per farm)	kg N ha^{-1}			
Cattle		9	9	8
Milk		28	40	49
N output total		36	48	57
N Surplus	kg N ha^{-1}	54	103	158
N use efficiency	%	40	32	26
Milk production N surplus	g N l^{-1}	10.2	13.5	17.3
Total surplus per farm	t N	4,364	10,866	22,760
Total surplus	t N	63,076	140,829	164,621

[a] Data are for financial years, i.e. 2012 represents 2011-12.

All N recovery measures deteriorated markedly over the 22 year period examined, though the adverse trend has moderated somewhat since 2006 (Figure 1). The whole-farm N surplus for the average dairy farm has increased from 54 to 158 kg N ha^{-1} between 1990 and 2012. Nitrogen use efficiency declined from 40 to 26%, while milk production N surplus increased from 10.2 to 17.3 g N l^{-1}. Total N surplus has also increased from 63,076 to 164,621 t N for the Australian dairy industry as a whole, despite a decline of 470,000 hectares in land used in dairying, suggesting a growing problem in terms of higher losses of reactive N.

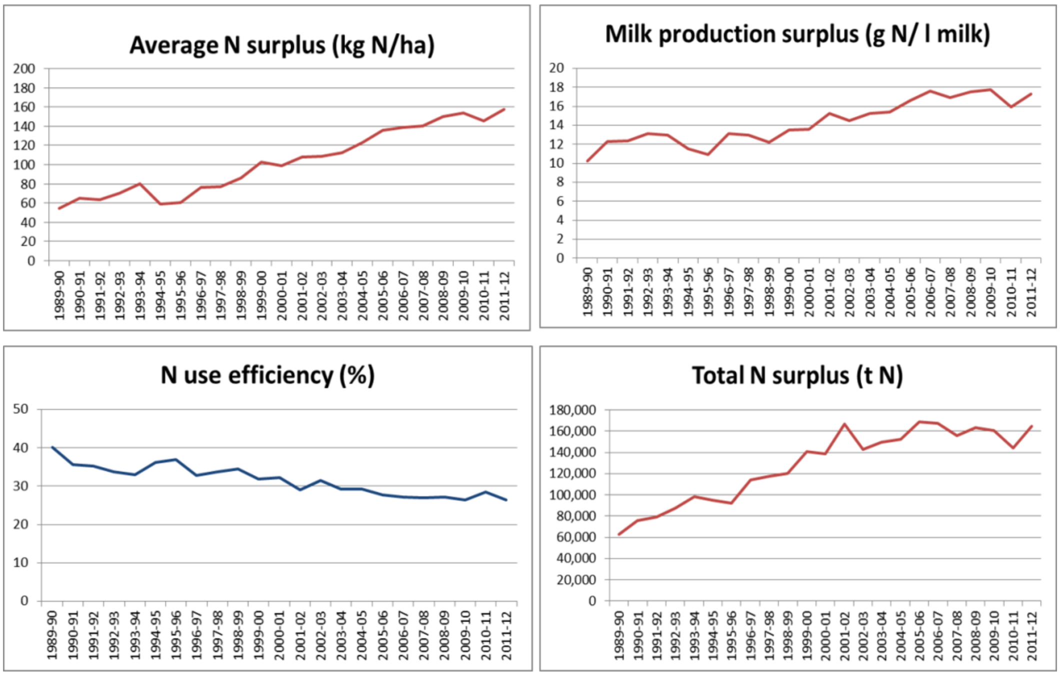

Figure 1. Trends in N surplus (a), milk production surplus (b), N use efficiency (c) and total N surplus (d), for the industry average Australian dairy farm between 1990 and 2012. Modified from Stott and Gourley (2016).

On-farm management strategies which have resulted in reductions in N surpluses and increases in N use efficiencies have included more strategic use of inorganic N fertilisers, optimising the recycling of home-produced manure, and lowering nutrient concentrations in cow diets (Oenema *et al.* 2011). Although factors outside of management control, such as climate and soil characteristics, will undoubtedly influence the efficiency of fertiliser N use by pastures and crops, there is likely to be further improvements through better management of applied N (MacKenzie *et al.* 2003).

While the practice of year-round grazing, generally means that only a small proportion of dairy manure is collected in Australian dairy systems (Gourley *et al.* 2012b), this is often applied to readily accessible paddocks adjacent to the dairy, with high loading rates on a small proportion of total land available. Additionally, as cow numbers and reliance on manual feeding systems increase, continued poor redistribution of collected manure has the potential to result in lower overall recycling of manure N and greater N losses in the future. Consequently, further investment in collection, storage and redistribution systems will be required to better manage manure nutrients. Improving nutrient intakes and reducing the concentration of excreted nutrients may be more difficult on grazing-based dairy farms compared to confinement based farms (Gourley *et al.* 2012b), particularly when pasture comprises the majority of the diet. However better balanced diets can result from improved selections of imported feeds. For example, the use of maize silage presents opportunities to better balance energy and crude protein levels (as measured by milk urea N concentrations) and reduce urinary N concentrations.

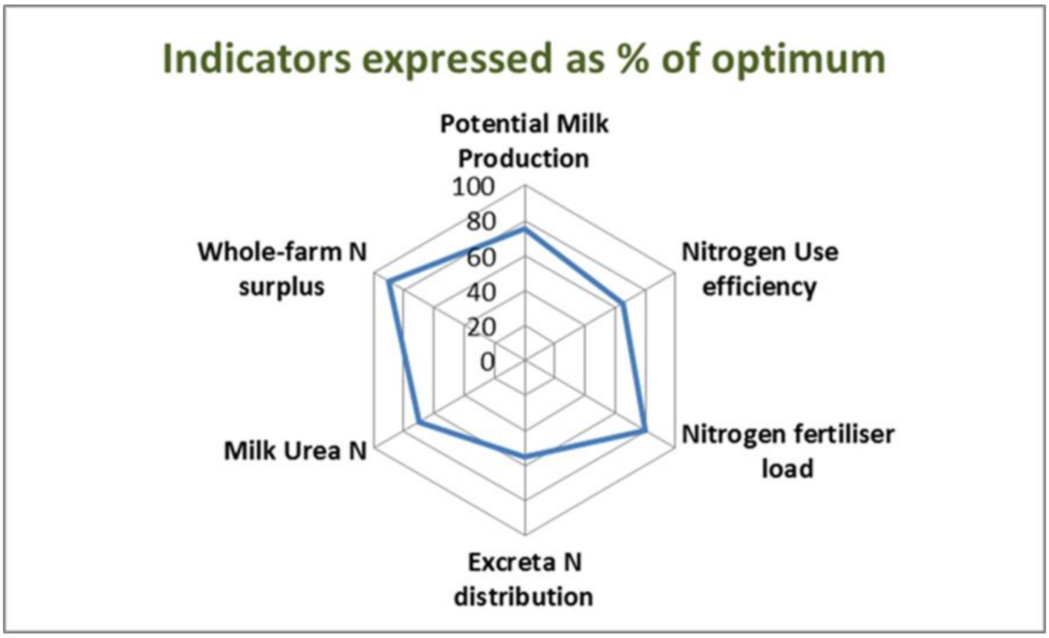

Figure 2. Proposed farm and nitrogen use performance indicators at the whole-farm and component scale.

The diversity and compexity of management practices on a modern dairy farm and the associated pathways and transformations of N fluxes, highlight the need for a suite of whole-farm as well as within-farm indicators specific to management options (an example of potential within-farm N indicators is provided in Figure 2). These indicators should be developed along with farmers and industry advisors to meet the duel goals of production and environmental performance, utilise readily available farm-based information and enable bench-marking and guidance for improvement.

Conclusion

Whole-farm N accounting can provide useful performance indicators, which can be internationally comparable. For the Australian dairy industry, the use of long-term industry data to determine an industry average WFNB has demonstrated a continuing decline in N recovery metrics as current grazing-based dairy farms continue to intensify. These indicators can be used to focus industry efforts on increasing N use efficiency and reducing N emissions from dairy farms. The further development of within-farm N efficiency indicators will also assist farmers and advisors to target specific mitigation options. However these additional efforts are likely to need cost-effective policy measures and future technological advances.

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