Nitrogen use efficiency indicators designed for the diversity of global dairy production systems.

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Abstract

Whole-farm nitrogen (N) budgets are determined to derive N use efficiency (NUE) and N balance estimates, useful for assessing the risk of N losses for dairy production systems. Component-based N indicators, applicable for the cycling of N through the soil, pasture/crop, animal product and excreta continuum, provide greater insights into key N fluxes and transformations impacting N recovery and farm productivity, leading to improved management. However, methods for calculating and utilising these indicators for the diversity of dairy systems globally are often inconsistent. This paper reports on the development of N efficiency metrics which ensure an appropriate framework for international reporting and interpreting.

Keywords: Animal NUE, Crop NUE, Dairy systems, Nitrogen Use Efficiency (NUE), Whole farm NUE.

1. Global dairy production systems

Global milk output in 2018, estimated at 843 million tonnes, ranks among the top five agricultural commodities and follows a long-term growth trend (~2% p.a.). On-going production gains result from higher dairy herd numbers and increased yield per cow, along with improvements to milk collection processes (FAO 2019). Milk animals are raised in a variety of production systems which can be categorised as: specialized landless systems, market-oriented dairy-crop systems, subsistence-oriented dairy-crop systems, and pastoral grazing-based systems. Of the 133 million holdings keeping dairy cattle, many farmers in developing countries keep herds of only 2 - 3 head, while in industrialised economies, herds are generally much larger. Farms with more than 100 cows represent less than 0.3% of all dairy farms globally.

2. Nitrogen flows in dairy production systems

Nitrogen can be imported onto a dairy production system in the form of fertilizer, feed, animals, through the fixation of atmospheric N by legumes, and to a lesser extent in bedding, irrigation water or by atmospheric deposition. Nitrogen exports are generally in milk, animals, manure, grains and forage. The major nutrient flows, transformations and stores that occur within a dairy farm include: (i) the addition of fertilizer and other plant nutrient sources to soil; (ii) uptake by crops and pasture; (iii) animal intake as feed; (iv) partitioning to milk, increased body mass and calves; (v) excretion in manure (urine and dung); and vi) the managed and unmanaged recycling of manure to soils (Figure 1).

Manure N may be directly deposited to land by grazing animals or collected where animals are confined, and later land applied. Alternatively, dairy manure can be used as an energy source for bio digestion or combustion (e.g. of collected, dried dung).

Losses of N within dairy production contribute to NO_3^- in surface and groundwater and NH_3 and N_2O emissions to the atmosphere, with increased losses attributed to high stocking rates, an imbalance between on-farm N imports and exports, concentrated N inputs in parts of the production system and associated inefficiencies in N use (Oenema et al. 2006).

3. Definitions of N performance indicators

NUE is defined as N output as a percentage of N input, whilst N surplus is the difference between N input and N output (Powell et al. 2010). These metrics are commonly expressed at various scales, from national, regional, whole-farm, crop, and even to animal (de Klein et al. 2017).

The recent EU Nitrogen Expert panel report (2016) provides excellent guidance for farm-scale N budget calculations. Total N input must include all purchased fertilisers, composts, feed, planting materials, bedding material, as well as atmospheric deposition and biological N fixation. Total N outputs include all animal and crop products. Exported manure should be considered as a negative input, while the efficiency of production of N inputs as imported feed should be accounted for as part of the N efficiency assessment. There are therefore methodological challenges with measuring the parameters needed to calculate NUE across the breadth of global dairy production systems, including defining system boundaries and accurately quantifying fluxes i.e. N fixation, atmospheric N deposition, alternative manure N losses and feed N.

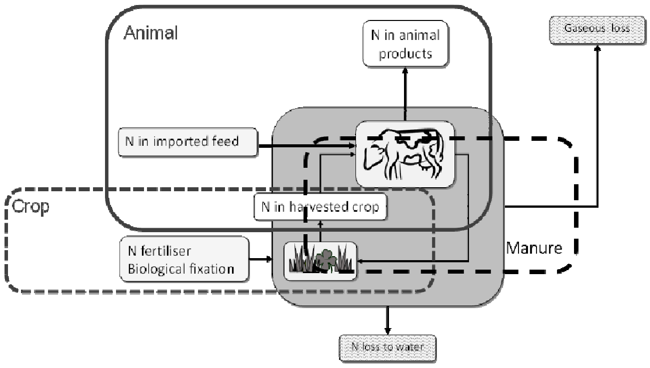

Figure 1: Representation of the N inputs and outputs that are typically included in the calculation of Whole farm NUE and N surplus values and sub-component efficiency assessments for Crop/home-grown forage, Animal and Manure reuse.

Improved management decisions are greatly aided by efficiency metrics which quantifiy N fluxes for the key components. In closed industrialised dairy production systems, inputs and outputs, such as fertiliser and harvested N in crops, feed N and milk N, can be readily estimated. However, estimating these parameters can be challenging in more open systems prevelant in developing countries.

4. Combined framework for reporting and interpreting N use efficiency indicators

The outcomes of this project will enable the global dairy sector and policy makers to: i) equitably benchmark systems in an international context; ii) identify systems and management decisions for improved dairy system productivity and reduced environmental losses; and iii) enhance between-region/country comparisons and allow tracking of performance improvements over time.

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