Nitrogen budgets for lowland temperate beef and sheep grazing systems: The North Wyke Farm Platform

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Abstract
The North Wyke Farm Platform comprises three 22 ha beef and sheep grazing 'farmlets' which are highly instrumented to monitor hydrology, weather, nutrient flows and productivity. Typical management for lowland UK grazing systems, based on permanent pasture, was applied to all three systems for an initial two-year baseline period. Following that, the platform has been progressively modified with the underlying principle being to improve the sustainability (economic, social and environmental) of two of the three farmlets, by reseeding of one with a grass-clover sward to drive production through nitrogen (N) fixation and one with a grass monoculture utilising the latest grass breeding advancements and higher yield potential. The third farmlet continued under permanent grassland. This paper presents the framework to be used in assessing the impacts of the reseeding period and to estimate system scale N budgets for the three systems. Data are being compiled with no results yet available, but will consist of a combination of measurements and modelled N pools and flows based on detailed management and production data. N use efficiency will be evaluated at the partial (forage production) and full (livestock product output) system level. A range of metrics expressing N flows on a product and land area basis will be derived. For a more complete understanding of the impacts of the system interventions and potential for future interventions to further improve NUE, further measurement data are required including N losses though denitrification, ammonia volatilisation and total N losses to water and N inputs through fixation.

Key Words
N use efficiency, grazing, reseeding, denitrification, ammonia volatilisation, N fixation

Introduction

There is increasing recognition of the role that grazing-based ruminant production systems (in comparison with intensively reared indoor systems) play in regard to food security and provision of wider ecosystem services (Eisler et al 2014). However, these systems are typically associated with low nitrogen (N) use efficiencies (Goulding et al., 2008) and losses of reactive N with subsequent environmentally damaging effects (Galloway et al 2003). Improvements to N use efficiency might be realized through the introduction of new technologies and management systems including improved crop and animal genetics, improved soil management, precision management of nutrient supply particularly with regard to spatial and temporal delivery, and improved livestock management.

The North Wyke Farm Platform (http://www.rothamsted.ac.uk/farmplatform) was established during 2010 as a UK national capability for collaborative research, training and knowledge exchange in agro-environmental sciences. Its remit is to research agricultural productivity and ecosystem responses to different management practices for beef and sheep production in lowland temperate grasslands. This paper uses the measurement and management data from the Farm Platform to assess the N pools and flows through the system over a defined baseline management period and through subsequent management interventions and to derive full and partial system level N budgets.

Methods

The North Wyke Farm Platform

Full details of the North Wyke Farm Platform design, construction and core measurements are given by Orr et al (2016), but briefly it comprises three 22 ha 'farmlets' with separate winter housing for cattle, silage clamps and manure storage for temperate lowland grassland beef and sheep production. Each farmlet consists of five hydrologically-isolated catchments, each catchment being one or two fields (Figure 1). Water leaving individual catchments (vertical movement restricted by a natural impervious clay-rich soil horizon) is channelled laterally through a network of French drains and perforated pipes to individual, fully-

instrumented flumes, which enable discharge to be measured and water to be automatically sampled and analysed for nutrient concentration and other water quality parameters in the catchment.

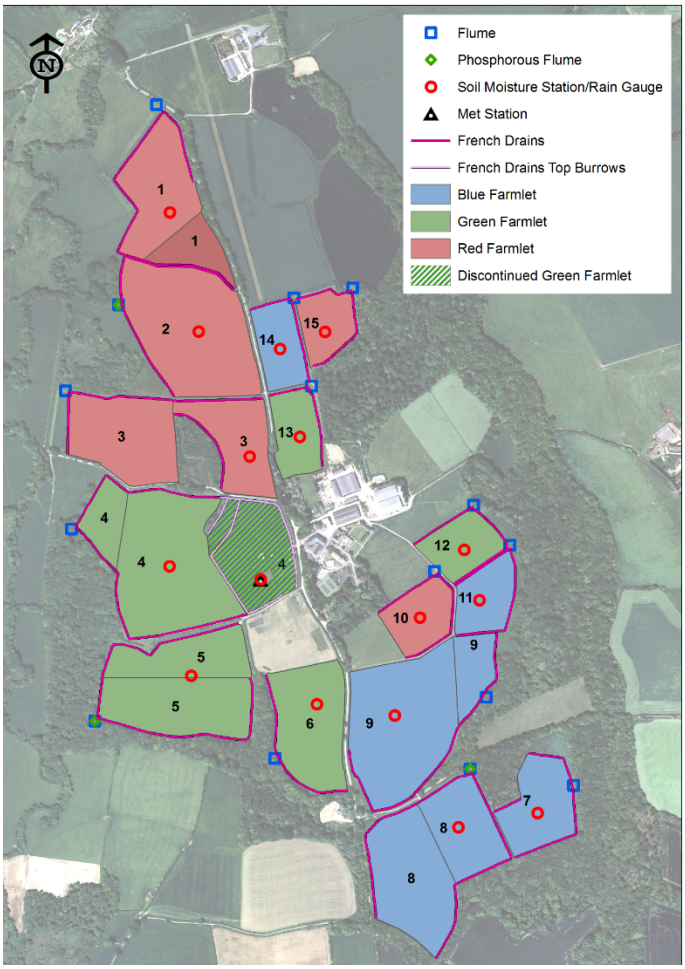

Figure 1. The North Wyke Farm Platform with permanent pasture (Green), reseeded grass-clover (Blue) and reseeded grass variety with higher yield potential (Red) farmlets (bounded at the edges by French drains) shown, together with the locations of the soil moisture stations and rain gauges (red circles), and flume laboratories (blue squares).

Each farmlet supports 25 or more (according to carrying capacity) beef cattle from weaning to sale. Calves from a spring-calving suckler herd are weaned and housed (straw bedded deep litter system) in the autumn of each year and then put to grazing over the summer period (duration depending on weather and soil conditions) and housed during the following winter period with finishing at 20 months. During the housing period the cattle are housed as three groups according to farmlet, receive silage made from that farmlet (with no concentrate supplementation) and manure from the housed cattle is returned to fields of the appropriate farmlet. A March-lambing flock of lowland cross-bred ewes provided the 50 ewes and their lambs per farmlet. The lambs were weaned in early July each year and moved to other catchments on their farmlet that had been cut for silage at the end of May.

Core measurements and management records made on the Farm Platform of relevance to this study include: fertiliser N inputs (rates, forms and timings); manure N inputs to pasture (rates and timing); numbers of animals, grazing days and live weight gain at pasture; pasture quality (protein content); inorganic N losses to water; soil nitrous oxide emissions (not continuous); silage quantity and quality (protein content); number of days, feed use and live weight gain in housing; manure production and composition from housed period; slaughter weights and killing out percentages.

Nitrogen budgets

Nitrogen budgets for the crop and animal components of the system can be derived based on the N inputs and outputs for each component (Figure 2), with the arrow between the crop and the livestock systems

representing the feed N, whether that be directly grazed forage or conserved forage stored (during which N losses may occur) and subsequently fed during housing. Indeed, budgets can be derived separately for the grazed and housed periods. The full system budget may omit detail of N recycled from animals to crop as manure (either as direct grazing returns or as stored manure from the housed period); this detail is important in understanding N cycling within the crop system. Nitrogen use efficiencies, defined as the N in product (i.e. feed N output for the crop system) as a proportion of the N input to the system can also be derived for each component or for the whole system.

It is not possible to estimate all of the shown budget components from the core measurements being made on the Farm Platform, for example N inputs through biological fixation, gaseous N losses through ammonia volatilisation and denitrification and total N losses through runoff (dissolved organic N not being measured). These values will be modelled based as far as possible on site-specific environment and management data (e.g. using the model SPACSYS for total denitrification losses, Wu et al 2016).

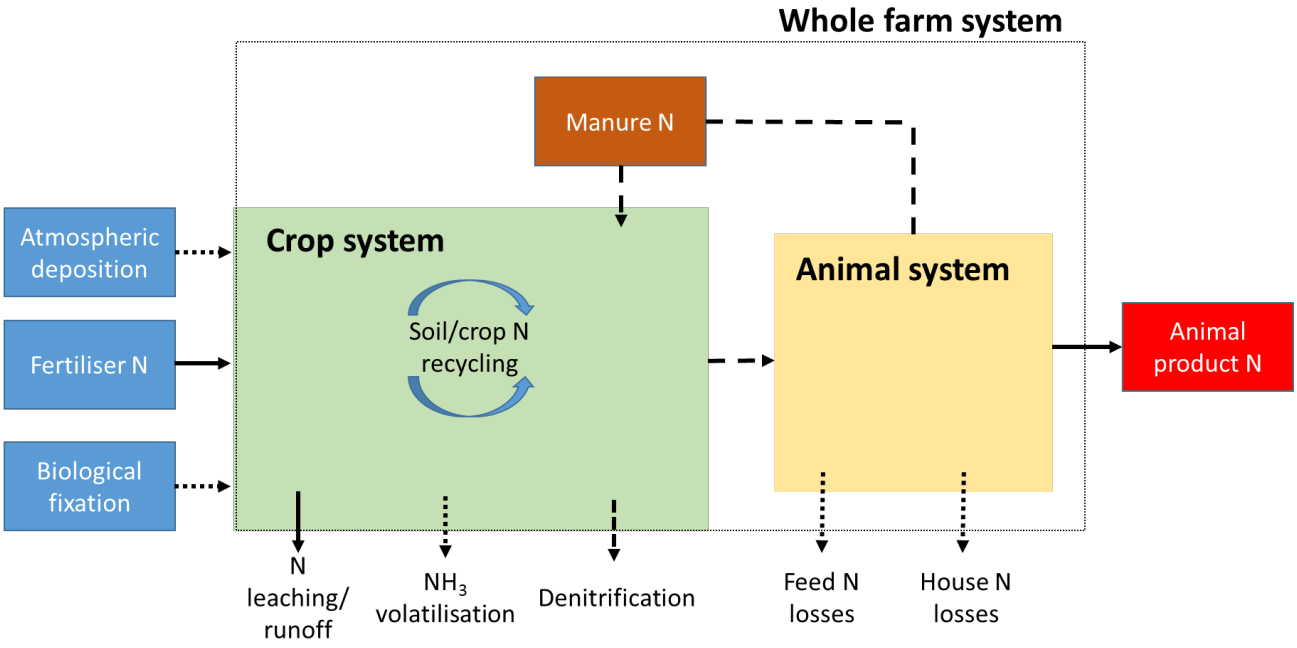

Figure 2. Schematic of N flows through the crop and animal components of the North Wyke Farm Platform grassland-based beef and sheep production system; solid arrows indicate measured flows, fine dashed arrows indicate modelled flows, broad dashed arrows indicate a combination of measurement and modelling

Metrics of nitrogen flow and utilisation
A range of metrics will be developed to quantify the different N pools and flows and total losses of reactive N to the environment on a per product or per land area basis for the baseline period across all three farmlets and for each individual farmlet through the management transition period.

Results
Data from the baseline and transition periods for the North Wyke Farm Platform are still being analysed and will be presented in full at the conference.

Conclusion
Comparison of whole system and component system N budgets using the framework described above can be made for the introduction of different forage types for beef and sheep production using the North Wyke Farm Platform, and conclusions based on these comparisons will be presented at the conference. Further quantification of some of the N pools and flows would enable more robust budgets and comparisons to be made, help to inform process understanding and the further development of potential management changes to further improve whole system N use efficiency.

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