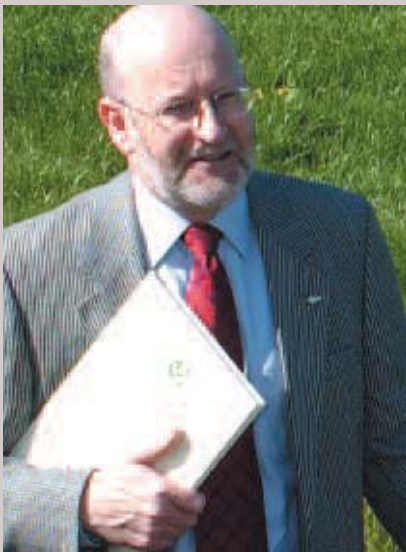




# AGRICULTURE and the ENVIRONMENT

**Mission:** To optimise crop yield and quality while protecting soils, water, the food chain and the global environment through the understanding, mathematical interpretation and modelling of biogeochemical cycling and the ecology and remediation of soils.



Head of Division:  
**Keith Goulding**

The work of several scientists from the Agriculture and Environment Division was acknowledged in 2003: Keith Goulding was awarded the Royal Agricultural Society of England Research Medal for his work on diffuse pollution; Steve McGrath, Phil Brookes and David Jenkinson were identified as being among the top 1% of cited authors in their fields; and papers on soil microbial biomass, written by David Jenkinson and colleagues, were identified as Citation Classics by the highest impact international soil science journal, *Soil Biology and Biochemistry*.

'Trigger molecules' (from labile substrates such as root exudates) were discovered that induce more expenditure of energy from the soil microbial biomass than is contained in the 'triggers'. Our hypothesis is that the biomass first senses traces of a substrate (trigger molecules) which then cause it to expend this energy in 'anticipation' of a more significant forthcoming pulse of substrate.

The Sulphate:Malate ratio test for sulphur deficiency in crops has been developed and is now in commercial use in partnership with Hill Court Farm Research, Gloucestershire.



# The Coates Farm study – nitrogen cycling at the farm system scale

Keith Goulding and Colin Webster



**Micrometeorological equipment used to measure ammonia losses from grazing cattle at Coates Farm.**

**Understanding the flows of nitrogen through farm systems is important for making profitable use of fertilisers and manures, and minimising losses to the environment. Losses of nitrogen by leaching have been the focus of much research since the EU set a maximum allowable concentration for nitrates in drinking water of 50 mg l<sup>-1</sup> in 1980, and the Government established Nitrate Vulnerable Zones (NVZs) to try and decrease losses. Research on nitrate leaching has been made at a range of scales and locations, often combined with measurements of other losses of nitrogen. It has spanned controlled laboratory experiments with a few grammes of soil, through field experiments, to studies of whole, working farms.**



**Part of the dairy herd at Coates farm that was moved to Elkstone Farm in 2000.**

With the Institute for Grassland and Environmental Research (IGER), North Wyke, and the Royal Agricultural College, we have spent eight years (1995-2003) studying the cycling of nitrogen on Coates Farm, a mixed dairy, sheep and arable farm in the Cotswold Hills, and nearby Elkstone farm: the Coates Farm Study. Our aim was to minimise losses of nitrogen whilst maintaining profitability.

### **Measuring flows of nitrogen on Coates Farm**

Coates Farm is 3 km west of Cirencester, Gloucestershire, where the thin (30 cm deep) stony clay loam soil over limestone is very prone to

leaching. From 1995-1999 (Phase I) the farm carried a dairy herd of 160 cows, with a sheep flock and some arable land. In summer 2000, because of the economic collapse of the dairy industry, the cows were moved to join a similar sized herd at nearby Elkstone Farm, leaving an arable and sheep system at Coates Farm (Phase II). Some of the grassland was ploughed.

The research concentrated on 10 'farmlets' (120m x 10m), located in fields that concurrently represented all parts of the farm system, and in which the nitrogen contents of all crops and soils were analysed. Quantities of purchased inputs, such as animal feed

and fertiliser, and sold outputs, such as milk and grain, were obtained from farm records, and the nitrogen contents of these obtained by analysis, official records or 'book values'.

Nitrate leaching was measured using ceramic cup samplers. In the last three years of the project, losses of soluble organic nitrogen were also measured using inert quartz/Teflon samplers. Gaseous losses by denitrification were measured in the 'farmlets' in years 1-5 and then calculated using the UK DNDC model. Ammonia volatilisation was calculated using IGER's Ammonia Emissions Inventory, with some tests to confirm its applicability to Coates

Farm. These used micrometeorological measurements of losses from a small group of cows grazing an enclosed part of one of the fields in the years 1-2. Atmospheric inputs of nitrogen were also measured.

Average nitrogen budgets at the 'farm gate' were calculated per hectare for each year. Total inputs minus saleable outputs gave the nitrogen surplus, i.e. the nitrogen in excess and therefore at risk of loss. Saleable outputs expressed as a percentage of total inputs gave the Nitrogen Use Efficiency (NUE).

### Nitrogen budgets, surpluses and efficiency of use

Average nitrogen budgets for the two farms are shown in Figure 1. The major input was always fertiliser. Inputs in animal feed concentrates at Coates Farm were almost eliminated in Phase II because of the removal of the dairy herd. Most of the nitrogen in saleable outputs was in arable crops. NUE at Coates ranged from 41% to 55%, the mean value for Phase I being 45% and for Phase II, 47%. Nitrogen surpluses ranged from 93 kg ha<sup>-1</sup> in the year the cows moved (2000-01) to 154 kg ha<sup>-1</sup> in 1997-8.

The farm gate budget for Elkstone (Figure 1) showed that the increased output of nitrogen in the milk from the larger herd did not account for the increase in inputs in feed: the NUE at Elkstone Farm, averaged over three years, was 20% with a nitrogen surplus of 336 kg N ha<sup>-1</sup>. Thus the specialist dairy farm uses nitrogen relatively

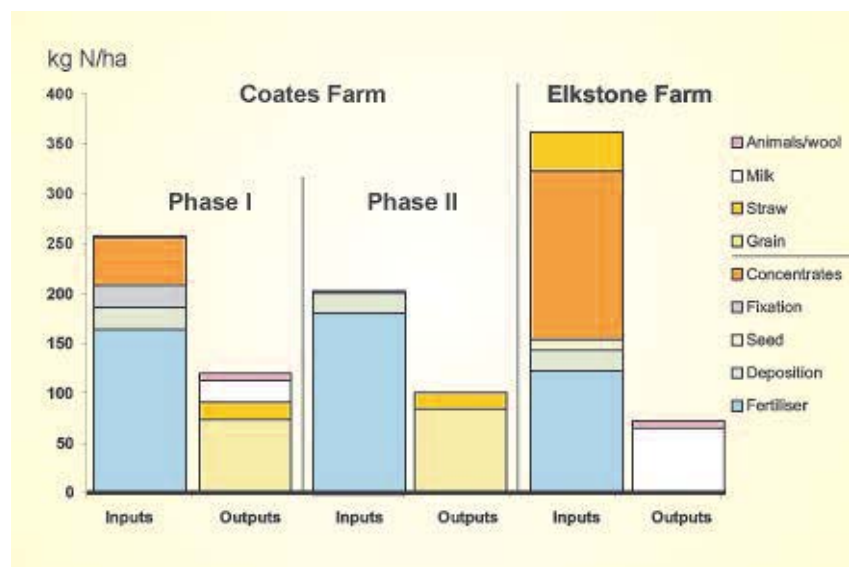


Figure 1. Nitrogen budgets for Coates and Elkstone Farms.

inefficiently and generates a large excess of unutilised nitrogen. Its inefficiency was not balanced by the small improvement in efficiency at Coates Farm: combining the nitrogen budgets for both farms for Phase II gave a NUE of 32% and an N surplus of 196 kg N ha<sup>-1</sup>. An economic driver clearly had an adverse impact on the environment.

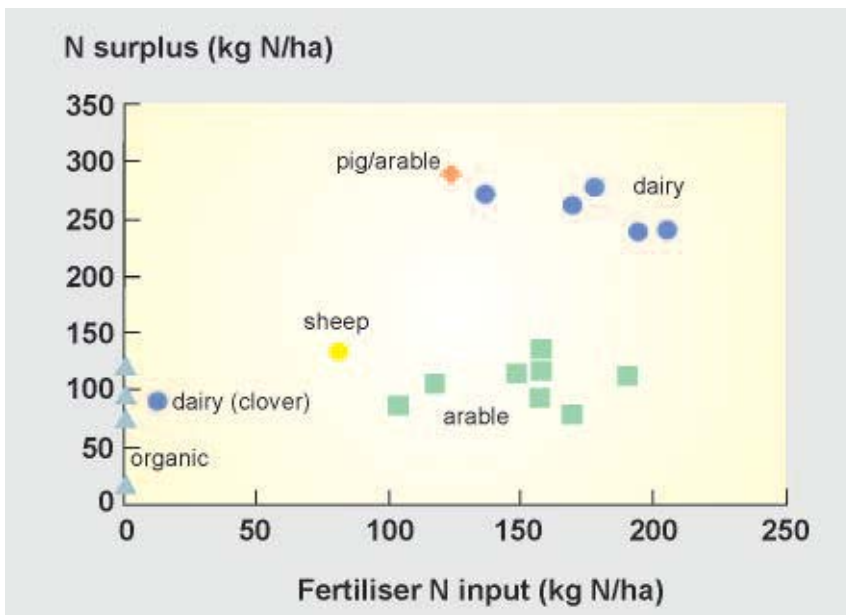
### Nitrate leaching

On the thin, freely-draining soil, nitrate leaching was always the main source of loss. There was great variation in the amounts of nitrogen lost, both between years, and between fields in the same year. In the driest winter, some fields lost less than 10 kg N ha<sup>-1</sup>; in the

wettest years some fields lost almost 200 kg N ha<sup>-1</sup>; the latter were grazed grassland, stubble turnips (*Brassica napus*) grazed by sheep in wet autumns, or fields that had received large quantities of organic manure, usually prior to growing forage maize. Average leaching losses in Phase II (87 kg N ha<sup>-1</sup>) were slightly less than in Phase I (92 kg N ha<sup>-1</sup>) but, because of the strong influence of weather conditions on leaching, this small difference cannot be directly attributed to the change in management.

### Using nutrient budgets to reduce pollution

The understanding gained from the research was shared with a farmer



**Figure 2. The nitrogen surplus for some Cotswold farms plotted against fertiliser inputs. (The surplus exceeds fertiliser inputs on livestock farms because of the inputs of nitrogen in animal feed.)**



**The removal of the dairy herd from Coates to Elkstone Farm was accompanied by the ploughing of old grassland and the release of nitrate.**

discussion group, assembled from existing local groups such as the British Grassland Society, the Maize Growers' Association, and the Cotswold Arable Study Group. Farm gate nitrogen budgets, nitrogen use efficiency and nitrogen surpluses were calculated using members' own farm records. Nitrogen surpluses are plotted against nitrogen inputs in Figure 2. There is much variation between the type of farm but also between farms of the same type, including organic farms, showing that there are opportunities for reducing surpluses.

The farmers discussed ways of reducing nitrogen losses and improving their nitrogen use efficiency, with the detailed analysis of Coates Farm as a reference. This stimulated farmers to consider how they calculated their fertiliser requirements, how efficiently they recycled manure, and how much feed they gave to livestock. Most identified an action that would reduce nitrogen inputs, or losses, thus improving their profit.

Simple farm gate budgets, backed by sound science and effective knowledge transfer, increased farmers' appreciation and understanding of nutrient flows on their farms. The research stimulated action to improve the efficiency of nitrogen use, reducing environmental impact – a 'Win-Win' situation.



**An aerial photograph of Coates Farm, Royal Agricultural College, Cirencester.**