Nutrient budgets as a tool for researchers and farmers

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ABSTRACT

Whole-farm budgets for N, P and K have been determined for the organic dairy farm at Trawsgoed in mid-Wales and used to assess the potential value of budgets as a management tool for optimising nutrient use. Most of the information needed by farmers to calculate whole-farm budgets is available on commercial farms but an important limitation is the difficulty of estimating N fixation. Whole-farm budgets do not provide sufficient information for use in managing nutrient flows, which requires more-detailed field budgets. Information for determining budgets at the field scale is less readily available. The studies have examined the use of farm and field budgets to provide an estimate of the nutrient content of animal manures and slurries produced on the farm.

Keywords: organic farming; nutrient budgets; slurry; manure; dairy; nutrient management; resource use.

INTRODUCTION

Whole-farm budgets, comparing the quantities of nutrients entering the farm with the output in products, provide a relatively easily determined measure of likely changes in the nutrient status of farms. They can provide an early indication of potential problems arising from (i) a nutrient surplus (inputs>outputs), leading to an accumulation of nutrients and increased risk of loss or (ii) a deficit (outputs>inputs), depleting nutrient reserves and increasing the risk of deficiencies and reduced crop yields. These simple budgets help farmers and researchers to understand the factors influencing the farm nutrient status. They also provide regulatory authorities with a readily-determined, comparative indicator of environmental impact. However, the simplest farm-gate budgets derived solely from farm records of purchases and sales are of little value for organic systems as they omit biological N fixation, which is generally the main form of N input to these farms. More complex budgets, including estimates of internal flows of nutrients within the farm, offer greater possibilities to farmers and researchers for improving the efficiency of nutrient use. Such budgeting may be of particular value on organic farms where nutrient supplies may be more limited than in conventional agriculture.

METHODS

Budgets for N, P and K have been determined for the Ty Gwyn dairy farm at IGER, Trawsgoed for each year since the farm was converted to organic management in 1992 and used to assess the potential benefits of budgets as a farm management tool. The main characteristics of the farm are described in Table 1.

Table 1. Characteristics of Ty Gwyn farm, Trawsgoed (mean 1995-98).

Farm area (ha)	63	Cows in herd	80
% as grass/clover ley	70	Overall livestock units/ha	1.7
% as permanent pasture	23	Concentrates (t/cow)	1.26
% cereals (whole-crop silage)	7	Milk production (l/cow)	5430

Farm records were used to obtain data on quantities of materials purchased and on milk and livestock sales. Samples of feed, bedding, milk and rainfall were collected for chemical analysis of their N, P and K contents. Published data were used to calculate the nutrient contents of livestock. Biological N fixation was estimated from measurement of clover yields in individual fields and the relationship of Van der Werff *et al*. (1994), modified to adjust for the effects of grazing. Information about internal flows of nutrients at Ty Gwyn was obtained from measurements of crop offtakes and of rates and nutrient contents of slurry/manure applications.

RESULTS AND DISCUSSION

Whole-farm budgets for Ty Gwyn are summarised in Table 2. These do not include estimates of losses or changes in nutrient storage within the farm; all of which are difficult to measure at the farm scale. The budgets show a moderately large surplus for N and small surpluses for P and K. The P and K surpluses are sufficient to approximately balance the quantities expected to be lost by leaching. The budgets demonstrated the importance of bought-in feed and bedding as sources of nutrients on organic farms and that relatively minor changes in the types of feeds purchased can have a significant effect on the final balance.

The studies indicated that most of the information required for calculating whole-farm budgets is likely to be available on commercial farms. Details of the quantities of materials entering or leaving the farm are normally included in routine farm records. Our analysis of feed samples indicated that published values of typical nutrient contents were in most cases sufficiently accurate for calculating budgets. However, information was sometimes lacking on P, and more particularly, K contents of compound feeds. The greatest uncertainties were associated with the estimates of the N input from biological fixation. These uncertainties will be even greater on commercial farms where there are few opportunities for detailed measurements of yields and clover contents.

The difference between inputs and outputs is a measure of the total loss plus changes in the quantity of nutrient stored in the system. In the absence of independent measurements of the relative magnitude of these storage and loss components, budgets must be interpreted with care. This is particularly true of organic farms where reserve forms of nutrients make an important contribution and where there can be appreciable changes in the size of the soil N pool during the rotation. Nitrogen fluxes and interactions are particularly complex and it is generally not possible to estimate losses and changes in soil-N without the use of models (e.g. Topp *et al.* 2001). There are large uncertainties associated with these modelled estimates and they frequently fail to fully account for the calculated surplus.

Table 2. Whole-farm nutrient budgets for Ty Gwyn averaged over the whole farm area (mean 1995 - 1998).

Inputs & outputs (kg ha^{-1} yr^{-1})	**Nitrogen**	**Phosphorus**	**Potassium**
Inputs			
N fixation	118	-	-
purchased feed	67	9.5	16.6
straw	5	0.4	5.9
livestock	2	0.6	0.2
rain	7	0.03	2.8
Total input	199	10.6	25.4
Outputs			
milk	34	6.2	9.8
livestock	8	2.4	0.6
Total output	42	8.6	10.4
Input – output	157	2.0	15.0

Whole-farm budgets provide information about likely changes in overall nutrient status but provide little information about how to manage nutrients efficiently within the farm. On organic farms, where inputs are likely to be limited, it is important that nutrient applications to fields should be matched to crop offtakes. To achieve this, some form of budgeting at the field scale is required. Unfortunately, data on inputs and crop offtakes for individual fields are less readily obtained than for whole-farm budgets. These internal fluxes are often large compared with the transfers into and out of the farm. A 10 t ha^{-1} (dry matter) grass silage yield will typically remove about 340 kg N, 35 kg P and 220 kg K ha^{-1}; similarly, a single application of slurry at 50 m^{3} ha^{-1} might supply 120 kg N, 20 kg P and 100 kg K ha^{-1}.

Although there are difficulties in obtaining the necessary data on commercial farms, some form of internal nutrient budgeting would be desirable and this could be extended to provide additional management information. For example, farmers often have little information about the quantities of nutrients applied in manures. We have investigated the use of farm budgets to provide an estimate of the nutrients available in manures and slurries. The total pool of nutrients in cattle slurry at Ty Gwyn was calculated from the nutrient surplus for the animal house/manure store. This was determined as the difference between inputs from purchased feed, home-grown feed and bedding and the output in milk and livestock during the housing period. Inputs to the animal house in conserved forage, home-grown grain and bedding were obtained from the outputs from the individual field budgets. The N balance included estimates of gaseous losses during housing and storage. The total volume of slurry was measured directly or estimated from typical values of the amount of excreta produced, plus the volume of bedding material, parlour washings and rainfall to the store and yard. An example of the calculation of P and K contents in slurry is shown in Table 3. In this internal budget, the largest input is from home-grown silage. The calculated P and K contents were similar to typical values published for dairy slurry from organic farms (ADAS, 2001). We are currently comparing the calculated nutrient contents with measured values from slurry applications at Ty Gwyn.

Table 3. Calculation of the nutrient content of cattle slurry at Ty Gwyn[a].

	Phosphorus	**Potassium**
Nutrient input to housed stock (kg)		
concentrates	182	346
silage	493	3757
bedding	4	22
Nutrient output during housing (kg)		
milk	112	177
liveweight gain	10	3
Input - output (kg)	556	3945
Estimated slurry volume (m^3)	1346	(at 6.3% dry matter)
Nutrient content of slurry (kg m^{-3})	0.4	3.1

[a]*Values refer to half the herd at Ty Gwyn after dividing the cows between two separate units and are not directly comparable with the data in Table 2.*

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