Nutrient budgets on organic farms: a review of published data

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ABSTRACT

On organic farms it is important that a balance between inputs and outputs of nutrients is achieved. This paper collates nutrient budgets collated at the farm scale for 88 farms in 9 temperate countries. The majority of budgets were compiled for dairy farms (56). All the nitrogen budgets showed an N surplus (average 83 kg N ha^{-1} $year^{-1}$). The phosphorus (P) and potassium (K) budgets showed both surpluses and deficits (average 3.4 kg P ha^{-1} $year^{-1}$; 13.7 kg K ha^{-1} $year^{-1}$). For all nutrients as nutrient inputs increased the surplus increased more significantly than the nutrient outputs. Overall, the data illustrate the diversity of management systems in place on organic farms, which consequently lead to significant variability in nutrient use efficiency and potential nutrient sustainability between farms. There are opportunities for almost all organic farmers to improve the efficiency of nutrient cycling on the farm and increase short-term productivity and long-term sustainability.

Keywords: organic farming; nutrient budgets; nutrient use

INTRODUCTION

Nutrient budgets are becoming increasingly accepted as a tool to describe nutrient flows within farming systems and to assist in the planning of the complex and coincident spatial and temporal nutrient management within rotational cropping and mixed farming systems (Watson & Stockdale, 1997). Organic farming systems emphasise reliance on ecological interactions and biological processes over direct intervention. As a result, the use of imported materials to build/maintain soil fertility is restricted (*e.g.* EU Regulation 2092/91). Achieving a balance between inputs and outputs of nutrients within the farm system is critical to ensure both short-term productivity and long-term sustainability (Fortune *et al*, 2000).

Depending on the farm management and the balance of inputs and outputs of nutrients, nitrogen (N), phosphorus (P) and potassium (K) budgets have been shown to range from deficit to surplus for organic farming systems (*e.g.* Fagerberg *et al*., 1996; Nolte & Werner, 1994; Wieser *et al.,* 1996). In this paper we have brought together nutrient budgets from published papers compiled at the farm scale from 88 research and commercial organic farms of different types in 9 countries with temperate climates; additional budgets in theses or unpublished reports have also been included, where they were provided. Full details of the data sources are provided by Watson *et al* (2002); additional data for some farms have been included in this analysis *e.g.* N budgets for the farms described by Løes (unpublished).

Nutrient budgets were compiled by considering all the inputs and outputs of nutrients as described in the papers to compile a surface budget at farm-scale (Watson *et al*, 2002). Inputs have been separated into purchased inputs excluding manure, purchased manure, fixation (N only) and deposition (N only) to allow the dependence of the farms on different input sources to be derived. The resulting nutrient surplus or deficit (? nutrient) for each farm is the difference between nutrients sold in plant and animal produce and nutrient inputs in feed, seed, supplementary nutrients, fixation and deposition (N only). This represents the amalgamation of any nutrient losses from the system and any change in the storage of nutrients within the system.

RESULTS

N budgets were the most commonly reported (88) followed by P (71) and K budgets (70). All of the N budgets show an N surplus. (Table 1; average 83 kg N ha^{-1} $year^{-1}$). However, the efficiency of N use in the farm systems is relatively low (average 0.3), except in the arable systems (where it was 0.8 and 1.0). The P and K budgets calculated show both surpluses and deficits (Table 1, average 3.4 kg P ha^{-1} $year^{-1}$, 13.7 kg K ha^{-1} $year^{-1}$). The horticultural systems studied all imported significant quantities of manure to the system and showed the highest average P and K surplus. However these systems also showed the highest variability in the nutrient budgets due to differences in crop rotation, management and yields achieved (Table 1). Very high efficiency values were obtained for P and K in systems operating with very low to no inputs and showing nutrient budgets in deficit. Inputs of P and K from weathering of soil parent materials are excluded from the budgets as compiled, which may represent significant inputs to the system (*e.g.* Goulding & Loveland, 1987). However, in many soils such high efficiencies coupled to negative nutrient budgets indicate that the system is not sustainable in the long-term. Greater attention should be paid to the long-term capacity of the soil to supply nutrients through weathering in the design of appropriate site-specific rotations for organic farming systems.

Of the 56 dairy farms for which complete N, P and K budgets are available, only 5 imported manure. On these farms this formed 23, 52 and 55% of the N, P and K inputs respectively. Across all the dairy farms 62% on average of the N inputs were derived from N fixation (range 19-87%). Other purchased inputs *e.g.* in animal feed, bedding material and supplementary fertilisers (P and K only) made up 25, 87 and 94% on average of the N, P and K inputs respectively. Across all the dairy farms studied, N inputs averaged 118 kg N ha^{-1} $year^{-1}$ (range 36-293), P inputs 9 kg P ha^{-1} $year^{-1}$ (range 0-54) and K inputs 17 kg K ha^{-1} $year^{-1}$ (range 0-66). Outputs of nutrients in products were also variable. N outputs averaged 28 kg N ha^{-1} $year^{-1}$ (range 8-76), P outputs 6 kg P ha^{-1} $year^{-1}$ (range 1-18) and K outputs

8 kg K ha^{-1} $year^{-1}$ (range 2-27). Increasing P inputs increased P output in products for the dairy farms (r^2 = 0.6885; n= 56) and the average efficiency calculated from the gradient of the relationship was 0.29. However, there was no similar relationship for N or K. For N, P and K there was a highly significant linear correlation between total input and the surplus (r^2=0.9289; 0.9267 and 0.9111 for N, P and K respectively, n=56).

Table 1. Summary of farm-scale nutrient budgets by farm type

		Surplus (Input-Output) kg ha^{-1} $year^{-1}$		
Farm type	**n**	**Mean**	**SE**	**Range**
N				
Arable	2	25.6	24.4	1.2 - 50.0
Beef	5	112.0	25.6	18.4 - 164.0
Dairy	67	89.5	6.9	2.1 - 217.0
Horticulture	3	194.2	100.7	91.0 - 395.6
Mixed	8	54.6	8.6	21.0 - 91.6
P				
Arable	1	-6.0		
Beef	4	-1.8	1.4	-6 - 0
Dairy	56	3.1	0.9	-6.5 - +36.0
Horticulture	3	38.9	26.0	1.7 - +89.0
Mixed	6	-2.4	1.3	-6.9 - + 4.0
K				
Arable	1	57.0		
Beef	4	3.0	3.4	-4.5 - + 12.0
Dairy	58	9.6	2.0	-26.5 - + 58.0
Horticulture	3	122.0	88.0	-23.0 - +281.0
Mixed	3	-2.2	1.2	-4.4 - - 0.3

Overall, these data illustrate the diversity of management systems in place, even within one robust farm type on organic farms, which consequently lead to significant variability in nutrient use efficiency between farms. There is a need to identify best nutrient management practices for organic farms. There are opportunities for almost all organic farmers to improve the efficiency of nutrient cycling on the farm and increase short-term productivity as well as long-term sustainability.

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