RESEARCH TOPIC REVIEW: Nutrient budgets for organic farming

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Scope and Objectives of the Research Topic Review

1. based on the research and practice of Nutrient Budgeting (NB) provide a draft of a guide for farmers, advisers and others on the theory and use of NB
2. identify all the relevant organic and where appropriate the non organic research undertaken on nutrient budgeting and related subjects
3. identify sources of nutrient input/output data for nutrient budgeting, and based on available information make recommendations on updating existing data for populating a NB tool, noting any missing or unreliable data
4. identify currently available Nutrient Budgeting tools that have potential for application to organic farming, asses their methodology and make recommendations on what modifications are required in the light of the information identified in this Review.

A Nutrient Budgeting Guide has been prepared and can be found at Appendix 1.

1. The list contains Defra, SEERAD and EU funded research projects known to have included an element of research on nutrient budgets in organic farming. The most important projects are OF0316, OF0178, OF0126, OF0191, OF0332, OF0180 (and its successor), SAC/257/00.

Table 1: Research projects with a nutrient budgeting component

Project title	Organisation	Reference No/Code	Start date	End date
Understanding soil fertility in organically farmed soils	ADAS	OF0164	01-Apr-99	31-Jul-02
Modelling manure NPK flows in organic farming systems	ADAS	OF0197	01-Sep-00	31-Mar-02
The development of improved guidance on the use of fertility building crops in organic farming	ADAS	OF0316	01-May-02	30-Apr-05
Assessing the sustainability of a stockless arable rotation	ADAS	OF0318	01-Apr-02	31-Mar-05
Testing the sustainability of stockless arable organic farming on a fertile soil	ADAS	OF0145	01-Apr-98	31-Mar-01
Improving N use & performance of arable crops on organic farms using an expert group approach	ADAS	OF0178	01-Jan-99	31-Dec-01

Extension to OFO145: testing the sustainability of stockless arable organic farming on a fertile soil	ADAS	OF0301	01-Apr-01	31-Mar-02
EFRC stockless	EFRC		10-Jan-97	31-Dec-98
Conversion to organic field vegetable production Phase 1 (extended into OFO191)	HDRA	OF0126T	01-Aug-96	31-Jul-00
Conversion to organic field vegetable production Phase 2 (continued from OFO126T)	HDRA	OF0191	01-Aug-00	30-Apr-04
Organic field vegetable production - baseline monitoring of systems with different fertility building regimes	HDRA	OF0332	01-Jan-03	31-Mar-06
EU-ROTATE_N.	HDRA	QLRT-2001-01100	01-Jan-03	31-Dec-06
Organic Milk Production (extended into OFO317)	IGER	OF0146	01-Oct-98	30-Sep-02
Influence of level of self-sufficiency on the nutrient budgets of an organic dairy farm	IGER	OF0180	01-Oct-99	30-Sep-02
Optimisation of phosphorus and potassium management within organic farming systems	Rothamsted Research	OF0114	01-Jan-98	31-Dec-00
Key factors in sustainable ley-arable farming systems: quantifying the effects of crop rotation, vegetation management and animal health status on nitrogen and energy flows.	SEERAD	SAC/093/95	01-Apr-95	31-Mar-00
Resource use in organic farming	SEERAD	SAC/257/00	01-Apr-00	31-Mar-05

The following refereed publications are particularly relevant and widely available. Many of these are from UK research but some publications from know European projects are included. There is also a large body of relevant conference proceedings but many are difficult to access. Many of the conclusions from the review Watson et al. (2002) still stand.

ANDRIST-RANGEL Y, EDWARDS AC, HILLIER S & OBORN I 2007. Long-term K dynamics in organic and conventional mixed cropping systems as related to management and soil properties. Agriculture, Ecosystems & Environment 122**,** 413-426.

ASKEGAARD M & ERIKSEN J 2000. Potassium retention and leaching in an organic crop rotation on loamy sand as affected by contrasting potassium budgets. Soil Use and Management 16**,** 200-205.

BAKKEN AK, BRELAND TA, HARALDSEN TK, AAMLID TS & SVEISTRUP TE 2006. Soil fertility in three cropping systems after conversion from conventional to organic farming. Acta Agriculturae Scandinavica Section B-Soil And Plant Science 56**,** 81-90.

BERRY PM, STOCKDALE EA, SYLVESTER-BRADLEY R, PHILIPPS L, SMITH KA, LORD EI, WATSON CA, FORTUNE S 2003. N, P and K budgets for crop rotations on nine organic farms in the UK Soil Use and Management 19, 122-118.

FOWLER SM, WATSON CA, WILMAN D 1993 N, P and K on organic farms: herbage and cereal production, purchases and sales. Journal of Agricultural Science, Cambridge 120, 353-360.

FREYER B & PERICIN C 1993. Methods of nutrient balancing and their application in the example of three organic farming operations. Landwirtschaft Schweiz 6**,** 611-614.

GOSLING P & SHEPHERD M 2005. Long-term changes in soil fertility in organic arable farming systems in England, with particular reference to phosphorus and potassium. Agriculture, Ecosystems & Environment 105**,** 425-432.

GUSTAFSON GM, SALOMON E, JONSSON S 2007 Barn balance calculations of Ca, Cu, K, Mg, Mn, N, P, S and Zn in a conventional and organic dairy farm in Sweden. Agriculture ecosystems and Environment 119, 160-170.

GUSTAFSON GM, SALOMON E, JONSSON S & STEINECK S 2003. Fluxes of K, P, and Zn in a conventional and an organic dairy farming system through feed, animals, manure, and urine - a case study at Ojebyn, Sweden. European Journal of Agronomy 20**,** 89-99.

HAAS G, DEITTERT C & PKE U 2007. Farm-gate nutrient balance assessment of organic dairy farms at different intensity levels in Germany. Renewable Agriculture and Food Systems 22**,** 223-232.

HARALDSEN TK, ASDAL A, GRASDALEN C, NESHEIM L & UGLAND TN 2000. Nutrient balances and yields during conversion from conventional to organic cropping systems on silt loam and clay soils in Norway. Biological Agriculture and Horticulture 17**,** 229-246.

LOES AK & OGAARD AF 1997. Changes in the nutrient content of agricultural soil on conversion to organic farming in relation to farm-level nutrient balances and soil contents of clay and organic matter. Acta Agriculturae Scandinavica Section B-Soil And Plant Science 47**,** 201-214.

LOES AK & OGAARD AF 2001. Long-term changes in extractable soil phosphorus (P) in organic dairy farming systems. Plant and Soil 237**,** 321-332.

NICHOLAS PK, PADEL S, CUTTLE SP, FOWLER SM, HOVI M, LAMPKIN NH & WELLER RF 2004. Organic dairy production: A review. Biological Agriculture and Horticulture 22**,** 217-249.

OEHL F, OBERSON A, TAGMANN HU, BESSON JM, DUBOIS D, MADER P, ROTH HR, FROSSARD E 2002 Phosphorus budget and phosphorus availability in soils under organic and conventional farming. Nutrient cycling in agroecosystems 62, 25-35.

OLESEN JE & VESTER J 1995. Nutrient balances and energy use in organic farming - emphasis on dairy and cash crop farms. SP Rapport Statens Planteavlsforsog 1995**,** 143.

STEINSHAMN H, THUEN E, BLEKEN MA, BRENOE UT, EKERHOLT G & YRI C 2004. Utilization of nitrogen (N) and phosphorus (P) in an organic dairy farming system in Norway. Agriculture, Ecosystems & Environment 104**,** 509-522.

TOPP CFE, STOCKDALE EA, WATSON CA, REES RM. 2007. Estimating resource use efficiencies in organic agriculture: a review of budgeting approaches used. Journal of the Science of Food and Agriculture 87, 2782-2790.

VOS J & VANDERPUTTEN PEL 2000. Nutrient cycling in a cropping system with potato, spring wheat, sugar beet, oats and nitrogen catch crops. I. Input and offtake of nitrogen, phosphorus and potassium. Nutrient Cycling in Agroecosystems 56**,** 87-97.

WATSON CA, ATKINS T, BENTO S, EDWARDS AC, EDWARDS S.A. 2003 Appropriateness of nutrient budgets for environmental risk assessment: A case study of outdoor pig production. European Journal of Agronomy 20, 117-126.

WATSON CA & ATKINSON D 1999 Using nitrogen budgets to indicate nitrogen use efficiency and losses from whole farm systems: A comparison of three methodological approaches. Nutrient Cycling in Agroecosystems 53, 259-267

WATSON CA, BENGTSSON H, EBBESVIK M, LOES AK, MYRBECK A, SALOMON E, SCHRODER J & STOCKDALE EA 2002. A review of farm-scale nutrient budgets for organic farms as a tool for management of soil fertility. Soil Use and Management 18**,** 264-273.

3. The following list contains research projects known to have generated data which could be very useful for developing a more comprehensive approach to nutrient budgeting for UK organic farms. The MAFF/Defra funded units at High Mowthorpe, Redesdale, Terrington, Ty Gwyn and HRI are likely to hold particularly rich datasets. There is an important issue here in relation to accessing the information from both projects and farms as many of them are no longer run organically or owned by ADAS. Many of the project co-ordinators are no longer active in organic research. With respect to non-Defra funded research there may be Intellectual Property issues associated with availability of data. For example, the QLIF project run by Nafferton Ecological Farming Group is known to have an extensive data set on horticultural crops but the data is unlikely to be freely available. Collating these projects and the data for the Nutrient Budgeting Guide suggests data is particularly scarce for horticultural crops and livestock produce (e.g. eggs). Although recent projects have provided some data on nitrogen fixation, this is still difficult to predict because of the effect of different management practices and environment/soil factors. It is not always easy to find nutrient contents for bought-in feeds in the literature.

Table 2 Projects which contain useful data for nutrient budgeting.

Project title	Organisation	Reference No/Code	Start date	End date
Agronomic strategies and the economics of organic sugar beet	ADAS	BBRO 00/04	04-Jan-00	31-Mar-04

Understanding soil fertility in organically farmed soils	ADAS	OF0164	01-Apr-99	31-Jul-02
Modelling manure NPK flows in organic farming systems	ADAS	OF0197	01-Sep-00	31-Mar-02
The development of improved guidance on the use of fertility building crops in organic farming	ADAS	OF0316	01-May-02	30-Apr-05
Assessing the sustainability of a stockless arable rotation	ADAS	OF0318	01-Apr-02	31-Mar-05
Optimising the production and utilisation of forage for organic livestock	ADAS	OF0328	01-Aug-02	31-Aug-04
Testing the sustainability of stockless arable organic farming on a fertile soil	ADAS	OF0145	01-Apr-98	31-Mar-01
Optimising the synergism between organic poultry production and whole farm rotations, including home grown protein	ADAS	OF0163	08-Feb-99	31-Mar-02
Optimising production systems for organic pig production	ADAS	OF0169	01-Apr-99	30-Sep-02
Improving N use & performance of arable crops on organic farms using an expert group approach	ADAS	OF0178	01-Jan-99	31-Dec-01
Companion cropping for organic field vegetables	ADAS	OF0181	01-Jan-99	31-Dec-01
Efficient use of animal manures within an upland organic system	ADAS	OF0187	01-Apr-99	31-Mar-02
Extension to OFO145: testing the sustainability of stockless arable organic farming on a fertile soil	ADAS	OF0301	01-Apr-01	31-Mar-02
Woodchips as an alternative bedding material for livestock systems and the potential to produce an added value product from the composting of the resultant manure	ADAS		01-Jan-03	30-Apr-03

The development of isotopic methods to verify the authenticity of agricultural products	CSL	Q02009	01-Jul-00	30-Jun-03
Green Waste Composting	Duchy College	n/a	########	01-May-02
Alternative, non-animal based nutrient sources, for organic plant raising	EFRC	OF0308	01-Jan-02	31-Dec-02
EFRC stockless	EFRC		10-Jan-97	31-Dec-98
Organic cereal variety and mixtures trials	EFRC		01-Sep-99	31-Mar-06
Sheepdrove Monitoring	EFRC		01-Mar-02	31-Mar-05
Combining peas, monitoring and evaluation of the feasibility of organic production	HDRA		01-Mar-00	31-Mar-01
Use of green waste compost in agriculture	HDRA	Environmental Body Project 948082.001	01-Mar-97	31-Dec-00
Improving the sustainability of crop nutrition in horticultural soil	HDRA	HH3508SFV	01-Apr-04	01-Apr-08
Varieities and intergrated pest and disease management for organic apple production (LINK)	HDRA	HL0150LOF	01-Apr-00	31-Mar-05
Conversion to organic field vegetable production Phase 1 (extended into OFO191)	HDRA	OF0126T	01-Aug-96	31-Jul-00
Conversion to organic field vegetable production Phase 2 (continued from OFO126T)	HDRA	OF0191	01-Aug-00	30-Apr-04
Economics of organic top fruit production	HDRA	OF0305	01-Feb-02	31-Jan-05
Organic field vegetable production - baseline monitoring of systems with different fertility building regimes	HDRA	OF0332	01-Jan-03	31-Mar-06

EU-ROTATE_N.	HDRA	QLRT-2001-01100	01-Jan-03	31-Dec-06
Changes to soil quality indicators following conversion to organic vegetable production	HRI	OF0401	01-Apr-01	31-Mar-02
Crops for organic systems	IGER	IGER6199	01-Jun-02	31-May-03
Organic Milk Production (extended into OFO317)	IGER	OF0146	01-Oct-98	30-Sep-02
Clover: cereal bi-cropping for organic farms	IGER	OF0173	01-Jan-99	31-Dec-01
Influence of level of self-sufficiency on the nutrient budgets of an organic dairy farm	IGER	OF0180	01-Oct-99	30-Sep-02
Comparative Assessment of Environmental, Community & Nutritional Impacts of Consuming Fruit & Vegetables Produced Locally and Overseas	NERC	RES-224-25-044 (Food chains: Reearch project)	31-Dec-04	30-Nov-07
Shelf life of organic vegetables	NIAB	OF0156	01-Jun-98	31-May-01
Organic Grain Link	Norton Organic Grain	MQP19	01-Aug-02	31-Jul-05
Composting Apple Pomace	Project Carrot, Holme Lacy College		01-Jan-03	01-Apr-03
Optimisation of phosphorus and potassium management within organic farming systems	Scottish Agricultural College	OF0114	01-Jan-98	31-Dec-00
A study of the advantages & disadvantages of break crops for organic rotations	Scottish Agricultural College	OF0143	01-Oct-98	30-Sep-02
Key factors in sustainable ley-arable farming systems: quantifying the effects of crop rotation, vegetation management and animal health status on nitrogen and energy flows.	SEERAD	SAC/093/95	01-Apr-95	31-Mar-00

Resource use in organic farming	SEERAD	SAC/257/00	01-Apr-00	31-Mar-05
Monitoring Research and Development of Sheepdrove Organic Farm	SOF	SOF	01-Nov-02	01-Dec-03
Interactions between crop nutrition and soil borne diseases in organic protected cropping systems	Nafferton Ecological Farming Group	3562	01-Aug-01	31-Jan-04
Improving organic cereal production	Nafferton Ecological Farming Group	No code	01-Sep-02	31-Aug-06
Identification and analysis of optimum conversions strategies for stockless organic farming systems on the basis of agronomic and economic performance and applicability to different soil types and farm business situations.	University of Nottingham	2313	01-Mar-00	28-Feb-03
Investigating the long term impact of organic conversion strategies	University of Nottingham	2803	01-Oct-02	29-Sep-05
Use of green waste compost in agriculture	HDRA	Environmental Body Project 948082.001	01-Mar-97	31-Dec-00
Improving Quality and safety and reduction of cost in the organic and 'low input' food supply chains in Europe (QualityLowInputFood)	Nafferton Ecological Farming Group	N/A	01-Apr-04	31-Mar-09
Improving fertility management and disease control in organic and low input production systems for bread making wheat	Nafferton Ecological Farming Group	N/A	01-Oct-04	30-Sep-09
Improving fertility management and weed control in sustainable lupin production in the UK (LISA)	IGER	N/A	01-Jan-04	31-Dec-08
Environmental and biodiversity impacts of organic farming in the hills and uplands	Organic Centre Wales		01-Nov-02	31-May-03

Comparison of the physical and financial performance of organic dairy farming systems	University of Wales Aberystwyth		01-Oct-98	30-Sep-02
Phosphorus supply in organic farming	SAC	LK	01-Apr-06	01-Apr-10

Nutrient Budget Models

The nutrient flows within the farming system that are currently available and we have assessed within this project are NDICEA, Overseer, Fertility Building Crops model (FBC) (Cuttle, 2006) and OrgPlan. FBC only describe N flow within the cropping system. In contrast, NDICEA, Overseer and OrgPlan describe P and K as well as N. In addition, the global warming potential of livestock systems can also be assessed within Overseer.

Fertility Building Crops Model

The FBC model has been developed as a planning tool, which provides organic farmers with information on the availability of nitrogen at different stages following the ley phase of a rotation. It also provides an estimate of nitrogen losses from leaching and denitrification. However, it is only intended for use with crop rotations where there is a clearly defined ley phase and it describes the N flows in the subsequent five years.

NDICEA

The NDICEA model is currently being used successfully in the Netherlands to assess N flows within the rotation in organic arable farms. The inputs to the model are weekly weather data, manure and fertiliser applications, ploughing and harvest dates and the expected yield of the crop. Using this information, the model simulates the N dynamics within the system and the soil N-mineral level. Soil mineral N measurements are taken during the project so that the model can be calibrated for the field. However, many cases it has been found that the default soil values can be used. The outputs from the model are an N, P and K budget for the rotation, and graphs showing N leaching, dentrification, available N and the course of the mineral N throughout the seasons. The tool is very useful for understanding how the rotation impacts of the seasonal dynamics on N flows within the system; however, the NDICEA model does not take into account either nutrients inputs through seeds or nutrient offtake / inputs by livestock. Nevertheless, it is possible to describe grazing offtake in the model, and to simulate excretion by adding additional slurry.

OrgPlan

The OrgPlan is computer software which can be used to calculate a farm-gate budget, but has primarily been designed to aid farmers and advisors who are planning an organic conversion. The software consists of farm profile builder, rotation, cropping and livestock planner. Within the software there is a database for organic, in-conversion and conventional data. Hence, the software allows a number of scenarios to be evaluated for technical and financial feasibility by calculating farm-gate budgets for key resources and financial reports. The biggest challenge with OrgPlan is that data must be entered for all elements of the model, not just the nutrient budget. As a consequence, there is a lot of data to enter, and it is not always intuitive where you have to click to enter the data, and thus it is not simple to use.

Overseer

The Overseer model has been developed by AgResearch, New Zealand. The model combines nutrient budgets with indices derived from these nutrient budgets, to provide users with a tool to examine the impact of nutrient use and flows within a farm (as fertiliser, effluent, supplements or transfer by animals) on nutrient use efficiency and possible environmental impacts. The model also provides a means to investigate mitigation options to reduce the environmental impact of nutrients within a land use. The model is structured as three separate models which produce individual nutrient budgets for pastoral, cropping and horticultural systems. For the pastoral model, the model also produces a greenhouse gas report as well as a report on N and P. However, the greenhouse gas inventory is based on models and algorithms used for New Zealand's greenhouse gas national inventory, but with improvements to include on-farm management practices, and thus these would need changed to reflect UK conditions. The nutrient budget is adjusted for soil type and climate. Hence, the database in the model would have to be updated to reflect UK soil conditions. In order for the model to comprehensively describe the effluent management systems in UK, some additions would have to be made.

Currently, the biggest challenge for organic systems in the UK with the model is that the pastoral and cropping systems models are separate. Nevertheless, there is currently a project in New Zealand that is updating the crop and fodder crop N model, and it will probably end up capturing better an arable cropping system i.e. a farm with an integrated cropping/pasture system. However, to use the model currently for a grass / arable rotation, the farm would need to be split into two blocks, and assuming some transfer of N from the pasture to the cropping phase. In addition, for the pasture phase, leaching would be slightly over-estimated as the model doesn't take into account enhanced immobilisation that occurs when going back into the pasture phase from a cropping phase.

It is important to note here that any development work on Overseer for UK conditions would require UK funding.

Conclusions

NDICEA is a useful model to study the N flows throughout the season, and understand the N dynamics of the rotations and the influence of different cropping rotations on those dynamics. OrgPlan calculates a farm-gate budget. However, as the model is embedded in a package that assess the feasibility of converting to organic, the data entry is complicated and all the data for all elements of the programme must be entered before a nutrient budget is produced. The model Overseer also considers the internal flows within the systems. However, to be operable in the UK several modifications would have to be made. These include reflecting the UK soils and climatic conditions, additional effluent management systems, and it also may include changes to the fertiliser types stored within the database. The biggest challenge with the current version of Overseer is that pastoral and cropping sections are different and this would cause a challenge, although not insurmountable, for dealing with grass/arable systems, and there are plans to update the cropping model to included a cropping / pasture systems.

References

Cuttle, S P (2006) Development of the FBC model to estimate the nitrogen available from fertility - building crops in organic rotations. Poster presented at What can organic farming deliver? COR 2006, Heriot-Watt University, Edinburgh, 18-20 September 2006; Published in Atkinson, C; Ball, B; Davies, D H K; Rees, R; Russell, G; Stockdale, E A; Watson, C A; Walker, R and Younie, D, Eds. *Aspects of Applied Biology 79, What will organic farming deliver? COR 2006*, page pp. 259-262.

Appendix 1

A guide to nutrient budgeting on organic farms

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(Draft May 2008)

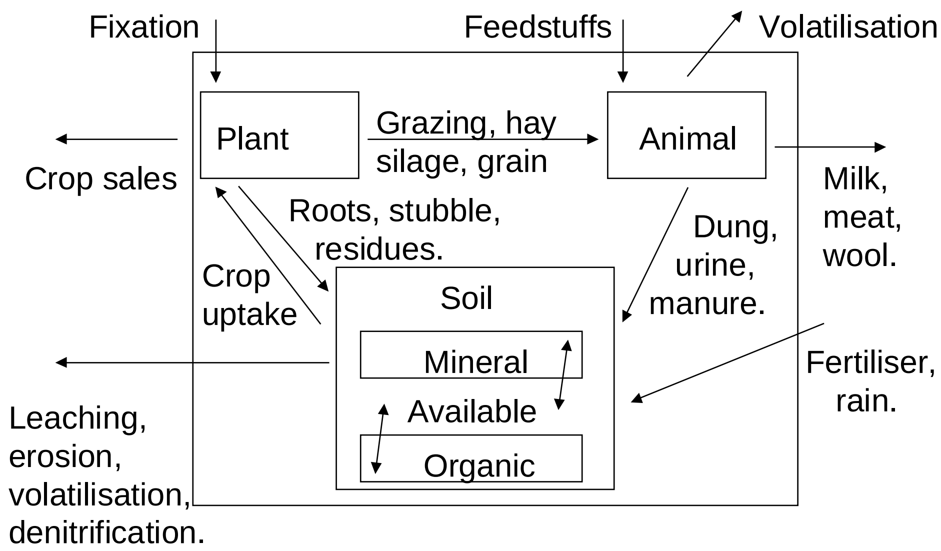
IOTA, SAC, Newcastle University
Funded by Defra

NUTRIENT BUDGETING

Introduction

Organic farmers aim to balance the inputs and outputs of nutrients in the farm or horticultural system (Figure 1). Nutrient management in such systems has a longer perspective than a single season or crop, due to the use of crop rotations and the inclusion of animals within the system. Where nutrient budgets can be simply and rapidly compiled for farms then they can be used both to assess potential deficits or surpluses of nutrients and to provide guidelines for nutrient management decisions.

Figure 1 *Nutrient flows in a farming system. Pools of nutrients in the soil, plants and animals are transferred in and out of the farm system and processes within the farm system link the pools.*



Nutrient budgets are commonly used in the following circumstances:

- As a tool to allow farmers and growers to make optimum use of available nutrients.
- To design and evaluate the viability and sustainability of arable and horticultural crop rotations by organic advisors.
- To assess an arable or horticultural rotation or whole farm system against organic production standards by an inspector.
- To indicate likely surpluses of nitrogen in the farm or horticultural systems and therefore risk of losses by leaching to ground and surface water, especially in Environmentally Sensitive Areas or Nitrate Vulnerable Zones.

Inputs and outputs for each nutrient are calculated and the surplus or deficit calculated (by applying the concept of mass balance). Although the types and amounts of inputs and outputs of nutrients vary between fields, farming systems and regions, nutrient budgets provide a framework that can be applied systematically across a range of systems and scales, for single fields, across complete rotations or for whole farm systems. Published figures are available for the nutrient content of harvested crops and for the inputs used. Measurements and estimates have also been made of the nitrogen fixed by leguminous crops. Although these figures are based on laboratory analysis of a large number of samples and will be correct on average across the UK, there are considerable variations in crop quality and yield, nutrient contents of manures and in the actual amounts of nitrogen fixed by legumes in any season. Consequently budgets cannot be used to give exact recommendations and the results should be interpreted carefully.

Ideally, nutrient budgets should be used in conjunction with a regular programme of soil analysis. Soil analyses measure the levels of available nutrients in the soil and can be used alongside budgets to plan the levels of additional nutrients required or to assess the long-term sustainability of the system. However, there is no simple way of measuring the potentially available nitrogen content of soil or the release rates of other nutrients into available forms in the soil. Nutrient budgets are therefore an important method to assess the viability of a rotation.

Nutrient budgeting has not been used in the UK to any great extent, except by professional consultants, where it has been used in the design of conversion plans. In other parts of the European Union, the method is more commonly used, both as a management tool and for regulatory purposes. In Denmark, 'budgets' must be produced at each inspection to be assessed by the inspection body. In the Netherlands, surpluses of nitrogen and phosphorus are calculated using nutrient budgets for all farming systems and large surpluses of nutrients are taxed.

The UK Compendium of Organic Standards in accordance with the EU Regulation sets outs the means by which fertility should be maintained in organic systems (Box 1). In addition the Standards also allow the use of limited 'mineral fertilisers' which are set out in Annex 2 A of the Compendium. Some certification bodies (CB) have further restrictions on the use of materials and you should check your own CB Standards.

Box 1: Extract from Council regulation (EEC) No 2092/91

2.1 The fertility and the biological activity of the soil must be maintained or increased, in the first instance, by:

(a) cultivation of legumes, green manures or deep-rooting plants in an appropriate multi-annual rotation
(b) incorporation of livestock manure from organic livestock production in accordance with the provisions and within the restrictions of part B, point 7.1 of this annex;
(c) incorporation of other organic material, composted or not, from holdings producing according to the rules of this Regulation

With the increasing pressure from the EU and the Compendium for organic systems to become more self-sufficient and to reduce their reliance on brought-in manures, inspection bodies will, in future, be making greater use of nutrient budgets to determine whether the Standards are being met. Producers, advisors and inspectors will need to become familiar with the techniques involved in producing nutrient budgets and interpreting the results.

In this guide, we will give a basic introduction to nutrient budgeting. Procedures for the compilation of the simplest type of budget, sometimes known as a farm-gate budget, will be provided (Figure 2). These budgets are a useful first step in examining the nutrient flows of a field, rotation or farming system and require only the type of farm management information that should be readily available to most farmers. Care must be taken to ensure that the units of measurement used throughout a budget calculation are consistent. Within this guide kilogrammes and tonnes are dominantly used as measurements of weight and hectares for measurement of area.

More complex budgeting approaches are necessary to examine the full environmental impact of farming systems or to test the effects of changes in farm management strategies. These more complex budgets also examine the internal flows of nutrients within the farming system through crop residue and manure management etc. (Figure 3). The principles outlined in this guide also apply in these more complex budgets, but the calculation steps are more intricate and the use of computer programmes to compile such data is recommended.

Figure 2 *Farm-gate budget, which accounts for inputs and outputs to the farming system, but disregards internal cycling of nutrients. This budget requires information on purchases and sales, it requires limited management information on cropping areas, stock numbers, housing and manure practices.*

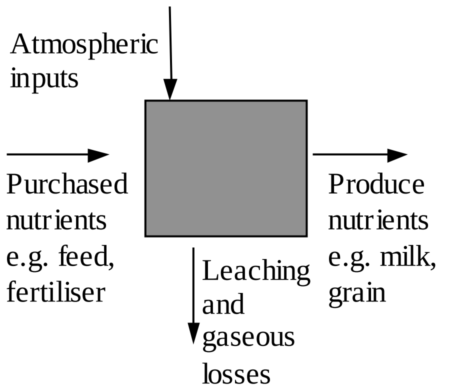
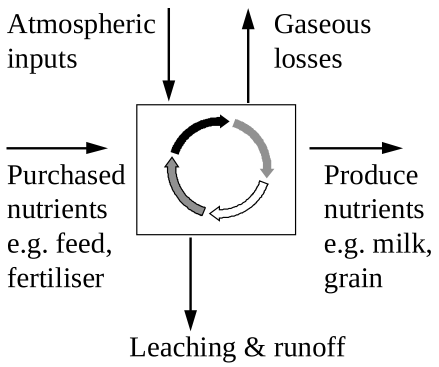


Figure 3 *Complex budgeting approach, which accounts for inputs and outputs to the farm system and estimates internal cycling. This allows an assessment of environmental impact and the testing of alternative management strategies.*



Nutrient Inputs

Nutrient inputs to a farm or horticultural system come mainly through nitrogen fixation by bacteria in the root nodules of legumes, purchased inputs (feeds, bedding, animal manures and permitted fertilisers) and in rainfall and deposition from the atmosphere (see Figure 1).

The possible nitrogen fixation under various types of legumes is given in Table 1for arable crops and Table 2 for horticultural crops. Values are given per tonne of crop harvested. However, the actual amount of nitrogen fixed is notoriously difficult to assess and the figures given are the median values of a range of measured values. Legumes will exploit the available nitrogen in the soil in preference to fixing atmospheric nitrogen, so amounts of nitrogen fixed will depend on soil fertility as well as the success of the association between the legume and its accompanying nitrogen-fixing bacteria. This often leads to lower total amounts of nitrogen fixed under grazed than cut leys, due to increased returns of nitrogen in excreta during grazing.

Other atmospheric inputs, in rain and dry deposition, vary across the UK (Figure 4). Atmospheric inputs may also be increased in close proximity to intensive animal production units due to increased deposition of ammonia.

Figure 4 *Three zones of the UK differing in the amount of nutrients deposited on the land surface.*
Zone 1 35 kg N, 0.1 kg P_2O_5*, 5 kg* K_2O
Zone 2 25 kg N, 0.06 kg P_2O_5*, 4 kg* K_2O*,*
Zone 3 15 kg N, 0.03 kg P_2O_5*, 3 kg* K_2O

Inputs of nutrients in seed or transplants are given in kilogrammes per kilogramme in Table 1 and 2.

Table 3 shows the contents of nitrogen, phosphorus, potassium, calcium and magnesium, in kilogrammes per tonne, for manures and fertilisers. Although average values are given for sources of bulky organic matter, nutrient contents of manures are very variable depending on animal type, diet, production level, bedding, housing and manure handling. Nutrient contents of green-waste and municipal composts are also variable due to different sources of raw materials and composting procedures. It is therefore recommended that manures and composts are analysed for nutrient content before application to land; actual values can then be used in the calculation of nutrient budgets. Average nutrient contents for bedding materials can also be found in Table 3 and should be included if they are brought-in.

Table 4 shows the nutrient contents of some brought-in feeds. The nitrogen content of feeds can be calculated from the crude protein contents, as each kilogramme of protein contains 0.16 kilogrammes of nitrogen. Wherever possible, actual analyses of feeds should be used to replace the average values given in the Table.

Nutrient Outputs

Nutrient outputs from farms and horticultural systems occur principally through sales of crop and animal products (see Figure 1). Losses from the system occur by volatilisation of ammonia occur during animal housing, from animal excreta during grazing and during manure handling, leading to losses of nitrogen in animal-based and mixed systems. Losses of nutrients may occur when soil is lost by water or wind erosion. However, such losses should be minimised in the UK by maintaining soil cover and avoiding cultivation of steep slopes, especially on light soils. Losses of nitrogen by denitrification and losses of all nutrients by leaching depend on the availability of nutrients in the soil at vulnerable periods and can be estimated from the nutrient surplus calculated in nutrient budgets.

Nutrient outputs are given in Table 1for arable crops and Table 2 for horticultural crops. Values are given per tonne of crop harvested. Typical yields for crops grown in organic situations are also indicated (derived from the Organic Farm Management handbook and other sources). However, actual yields will vary widely depending on the season and soil type and where possible actual yields or estimates gained from local experience should be used in place of average yields. The tables provided are not comprehensive and where a crop is not listed, using the figures for the nearest equivalent will give an estimate.

Nutrient outputs for animal products are given in Table 5. Actual or anticipated levels of farm production should be used. Data for livestock sales and purchases should be included. Volatilisation losses of nitrogen from animals can be estimated using Table 6a, while losses during application of manures are estimated using Table 6b.

Losses of nitrogen by leaching in an organic rotation are likely to be at their greatest following the ploughing of a ley and at a minimum under a long-term cut ley. Grazed leys or permanent pasture can also show significant losses of nitrogen by leaching. However, the nitrogen losses by leaching should be low when averaged over a complete rotation. Leaching of phosphorus, which may be a major cause of eutrophication of surface waters, is unlikely to be significant unless levels of available phosphorus in the soil are very high. However, significant leaching losses of potassium are possible on light soils or under uncovered manure heaps.

Calculations

A nutrient budget can be compiled for any one or all of the plant nutrients. Nitrogen is often the nutrient limiting crop growth and therefore it is often the first nutrient assessed when planning rotations. Where phosphorus or potassium levels are low in the soil, use of nutrient budgets may allow the use of supplementary fertilising materials to be planned. Calcium and magnesium are less important and can, if required, be ignored unless potential deficiencies make them significant, e.g. in fruit growing, glasshouse tomato production or with livestock. In practice the extra effort involved in completing a budget for all five nutrients is often negligible. Budgets are commonly compiled for an arable or horticultural rotation but can also be drawn up for whole farm systems.

Farm-gate budget

A simple format that can be used to compile a farm-gate budget for a whole farm is given. Calculation tables are given for a mixed farm, but the appropriate tables can be selected and adjustments to the calculations made, if a budget for a crop rotation or single enterprise is being compiled. All the calculations and tables presented in this guide are in kg or tonnes per hectare. Care should be taken to adjust yields or application rates recorded in other units before using the calculations outlined. Average yields or production levels can be used to make the calculations, for instance this may be necessary in planning a conversion or rotation. However, wherever possible actual yields should be used. Values are provided in the Tables for the nutrient content of inputs and outputs to the system. However, although these are the results of many laboratory determinations and may appear precise, actual nutrient contents may vary significantly due to *e.g.* soil type, season, and disease. Care therefore needs to be taken in interpreting the values produced by such budget calculations.

Crops
A form is provided to record the details of each crop on the farm separately, including leys and permanent pasture. On the initial forms, calculations are made per hectare. Where crops on different fields are managed identically and give similar yields, then they can be treated as a single crop.

Seed or transplant rates should be entered and the nutrient inputs in seed calculated from Table 1 or 2. Additional inputs of fertilisers or manures to that crop should be itemised and the nutrient inputs calculated using measured values or the values from Table 3. For a farm-gate budget, only purchased manures are recorded on this form. However, in rotation planning, inputs of manures from within the farm system may be included, as livestock production may otherwise not be included in the calculation. Where irrigation is used, then the volumes applied should be included as inputs. Where the nutrient content of the water is not known, then average values are provided in Table 3. Inputs of nitrogen by nitrogen fixation by legumes should also be calculated from Table 1 or 2. Total crop inputs for each crop per hectare can then be totalled.

For farm-gate budgets, crop outputs are only recorded where the crop product leaves the farm. Grain is not recorded as an output if it is fed to farm livestock. However, where grain, straw or silage etc. are sold then they should be recorded and the crop output calculated using Table 1 or 2. For rotation planning, crop outputs may be recorded where the crop leaves the field e.g. where straw is removed for livestock bedding. Liveweight gain and/or milk production of grazing stock may also need to be calculated. Care should however be taken that such production is not included twice, if livestock production is included explicitly in a whole farm budget.

Livestock
Livestock groups may be included separately on the form where they are managed differently or have different production levels. For a farm-gate budget, only the amounts of brought-in feeds and/or bedding are included here, and the nutrient inputs calculated using Table 4 and 3 respectively. Purchases of stock should also be listed and the nutrient input calculated. Nutrient outputs in sales of stock are calculated in a similar way. All livestock products, including milk, wool and any manure sold, should be listed and the nutrient outputs calculated.

Volatilisation losses of ammonia may represent a significant output of nitrogen from the farm system. Some losses result directly from animal excreta either during the grazing or housing period. These can be calculated using Table 6a. Losses are also associated with the spreading of manures to land. All applications of manure whether using purchased or on-farm sources, should be listed according to the type of manure applied. Volatilisation can then be calculated using Table 6b.

Summary
Details for the individual crops can then be entered on the summary sheet. It is important that these values are multiplied to give values simply in kg, to avoid any distortion of the overall budget where any crop occupies a significantly larger area and to allow livestock inputs and outputs to be included.

Deposition of nutrients in rainfall and by dry deposition can be calculated from the farm location (Figure 2) and the total cropped area.

Total livestock inputs and outputs should be entered on the summary form.

The nutrient surplus can then be calculated, first as a total number of kg. For interpretation it is useful to express this per hectare of cropped land.

Interpretation
Although the calculations outlined above lead to answers that appear precise, they only give a rough guide to what is happening within the farm system and should be interpreted with care. Soil analysis is an essential part of the assessment process and should be made at least once in every rotation cycle; at the same stage in the rotation and at the same time of year to aid interpretation of the results. A good time to take samples for soil analysis is at the beginning of the fertility building phase when nutrient levels are likely to be at their lowest. Changing farm management in response to the results of a nutrient budget should only be undertaken with careful professional advice.

Nitrogen
The surplus should be around 30 kg nitrogen per hectare per year where this is expressed for a complete rotation or whole farm. This nitrogen may be used to build soil fertility. However, most of the nitrogen surplus will be lost from the farm system by leaching or denitrification. Surpluses of nitrogen greater than 30 kg per hectare may indicate that the farm system is a significant pollution risk.

Phosphorus and potassium
Phosphorus and potassium should show a surplus close to zero. Potassium and phosphorus surpluses are likely to lead to a build up in the reserves of these nutrients held in the soil and only where the levels of available nutrients are already high are losses of phosphorus likely to occur. Potassium is more readily lost by leaching, especially on sandy soils. Many soils in the UK show high reserves of phosphorus and potassium in the soil and in these cases it may be acceptable for a farm system to show a deficit for phosphorus or potassium as these unnecessarily high reserves are used. However, such a situation should be carefully monitored. The combination of nutrient budgeting with soil analysis is especially important for phosphorus and potassium.

Calcium and magnesium
Where soils are regularly limed to maintain soil pH, the calcium budget is likely to be in balance. If magnesium deficits are indicated by nutrient budgets then dolomitic limestone or maglime might be used alongside ground limestone.

GLOSSARY

Rotation: a series of crops grown in succession on the same area of land

Ley: temporary grassland (usually of no longer than 10 years duration) used for cutting or grazing

Legume: plant of the order of *Leguminosae,* which are capable of forming a symbiotic association with *Rhizobia* bacteria. These bacteria form nodules on the roots of legumes and use carbon compounds produced by the plants as an energy source for nitrogen fixation (see later). Legumes include peas, beans, clover, lucerne and vetches.

System: anything made up of parts, which operate together to produce an outcome.

Budget: a financial statement, summarising income and expenditure, to allow planning of future expenditure. Any summary of inputs and outputs *e.g.* water budgets for irrigation scheduling, energy budgets

Mass balance: if a system is considered, then the inputs of any material to the system minus the outputs represent the change in storage within the system. *e.g.* If I have 3 apples, John gives me 2 (inputs) but Jane takes 3 (outputs), I have two apples left (change is –1). However, this can only be applied where all the inputs and outputs can be measured or estimated.

Deficit: the outputs from the system exceed the inputs, and the balance is therefore negative. The system may not be able to function, or the reserves held within the system will decline.

Surplus: the inputs to the system exceed the outputs, and the balance is therefore positive. If reserves are held within the system these will accumulate, or outputs may increase to balance the inputs.

Denitrification: process carried out by bacteria under anaerobic conditions in the soil causing gaseous losses of nitrogen.

Erosion: the movement of soil particles by natural forces, predominantly water and wind.

Eutrophication: enrichment of streams, rivers and lakes with nutrients carried in water draining from surrounding land. Where this process is accelerated, algal blooms can occur.

Leaching: loss of soluble forms of nutrients from the soil (nitrate, potash, phosphate) in drainage.

Nitrogen fixation: a small number of soil micro-organisms are able to use nitrogen directly from the air to form proteins. Some organisms are able to live independently in the soil, but the majority of nitrogen fixing organisms form a symbiotic association with plants, to form nodules on their roots. Nitrogen fixed by the micro-organisms is made available to the plants.

Volatilisation: rapid conversion of a material to a gas. Ammonia gas can be formed very rapidly, where materials are exposed to the air and contain large amounts of nitrogen in the form of soluble ammonium and the pH is near neutral, for example in manure turning or spreading.