Development of a calculator tool for estimating manure N and P outputs from farm livestock: ENCA“SH”

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Introduction

Excretal ‘standards’ for manure nitrogen (N) and phosphorus (P) output from livestock in England have been extensively reviewed (Cottrill and Smith, 007) as part of the proposed new Action Programme for Nitrate Vulnerable Zones, Regulations 2008 (Anon, 2007). These figures will form the basis for setting environmentally acceptable stocking rates, once new regulations have been agreed and implemented. However, it is clear that there are many factors likely to impact on excretion of surplus N and P during livestock production and, hence, such standards should be used for general guidance only. There will be many cases, at the individual farm level, where quite different figures for N and P excretion might be appropriate. For example, it is important that where producers are taking advantage of best practice or new technologies to reduce the N or P content of the diets fed, or have developed a more efficient production system, the impact on N and P excretal output should be taken into account.

ENCA“SH” (Estimation of Nutrient Content of Animal manures after Storage and Housing), a user-friendly Decision Support Tool (DST), has been developed that will calculate livestock manure N and P output on an individual farm basis. This will assist farmers in meeting the requirements of the NVZ Action Programme, in a convenient and transparent way. It is also thought that this will assist industry ‘ownership’ and acceptance of the output standards, provide an opportunity for knowledge transfer and may assist producers in improving the efficiency of their production system.

Approach

Calculations in ENCASH are based on the well-established nutrient balance method for mammals (Maynard and Loosli, 1969), which also forms part of the established criteria for the assessment of the nitrogen content of animal manures in the European Union (Ketelaars and van der Meer, 2000). The same approach has been taken with P (Cottrill *et al.,* 2005). It is assumed that the amount of N and P excreted in faeces and urine is the total consumed minus the N and P content in products (e.g. milk, meat, eggs, wool, liveweight gain etc) and may be summarised as:

N or P excreted = N/P consumed in feed – N/P in animal products

The level of detail of information required, and its availability varies for different livestock and production systems. Much of the data used to derive appropriate estimates of excretal output were obtained from recognised industry experts, specialists in nutrition involved in advising livestock producers (Cottrill and Smith, 2007).

Dietary N intake is a function of the total amount of feed consumed and the N content of the feed. Estimation of dry matter intake (DMI) and N is more difficult in cattle than for other livestock, due to the range and variability of the feeds available (e.g. grass/maize silage, variable access to pasture). For dairy cattle, DMI is predicted using the equation proposed by Ketelaars and van der Meer (2000) to establish nitrogen equivalents in livestock manures (Anon, 2002). An estimate of the protein content of forages, including fresh (grazed) grass, the main feed in the summer months, is available from past studies on

the composition of feedstuffs (MAFF, 1990), although many farmers have silage analysis undertaken as a routine for diet formulation. In balance calculations, the information on N and P content of animal products is usually based on research data, at least for content in liveweight gain, in meat, eggs and wool, although milk output and quality is routinely available to farmers from sampling schemes.

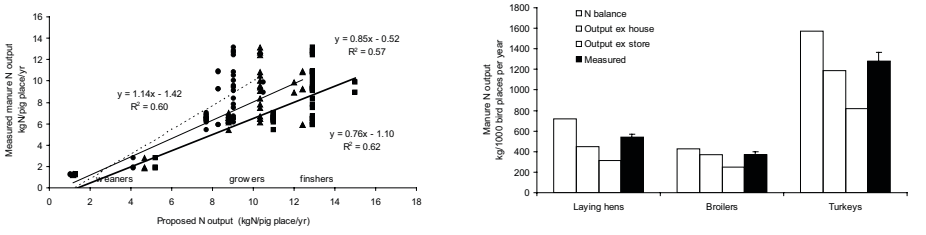
Following excretion, the potential for N loss via gaseous emissions during the storage of excreta in housing or in external storage structures, must be taken into account. This allows a more accurate estimate of manure N loading when manures are applied to land. The mass-flow model "NARSES" has been developed for estimating ammonia emissions from UK livestock production. The model takes account of ammonia emission factors established for different livestock and different phases of manure management (Webb and Misselbrook, 2004) and is now the accepted basis for the inventory of ammonia emissions from UK agriculture (Misselbrook *et al*., 2007). The mass-flow approach is important for understanding of possible interactions following changes in manure management and can thus represent the likely emissions from the range encountered on livestock farms. NARSES-derived emission factors for all the likely housing, manure management and storage options are stored within the DST and are accessed by ENCASH, according to operator selection (Figure 3).

Validation of the Approach

Some validation of this approach is available both at a coarse scale and from more detailed research data. In a recent study on commercial dairy farms in England and Wales, N and P excretion by dairy cows was estimated using a simple, whole-farm, nutrient balance approach. Data relating to imports onto the farm as fertilisers and feeds and exports as milk, livestock and manure, were collected for the year 2002, together with details of cow numbers, milk production and composition, and the cows' diet (Laws *et al,* 2004). On average, apparent annual surpluses were 143 kg N/cow and 8.5 kg P/cow over all farms. Adopting an application efficiency of 80% for fertiliser N use by crops (Scholefield *et al*., 1991) reduced the apparent N surplus from 143 kg N/cow per year, to 115 kg N/cow per year; i.e. very close to the 117 kg N/cow per year estimate proposed for average yielding dairy cows in the recent review (Cottrill and Smith, 2007).

Figure 1. Comparison of experimentally measured manure N outputs with proposed N output 'standards'; (a) for pigs based on N balance calculations with fresh excreta (■), excreta after N losses during housing (▲), excreta after N losses during housing and storage (●); (b) for poultry assuming fresh excreta (N balance), output after housing (ex-house) and after housing and manure storage (ex-store)

(a) (b)



Comparison of research measurements of manure N output with the proposed N standards for the main classes of pigs is summarised in Figure 1(a) (Cottrill and Smith, 2007). The research data included a range of diets and so the range in observed manure N output shown on the 'y' axis is to be expected and reflects the impact of diet. The proposed 'standard outputs' include estimates based on N balance and after allowance for losses

of N via gaseous emissions during housing and manure storage - according to typical management systems for pigs. Linear regression suggested that the measured outputs were around 25% below the N balance (fresh excreta) estimates. Allowing for housing and manure N storage losses improved the correlation; measured manure N outputs were c. 85% of proposed output ex-housing and at least equivalent to, or marginally in excess of, proposed output ex-storage (gradient of slope 1.14). The experimental observations were from in-house production phase only and did not include slurry storage. From similar research studies and from sampling and monitoring of commercial poultry units, data on total manure output are also available. Comparison of the measured manure N output (average of several observations), showed closest agreement with the proposed "ex-house" N output (Figure 1b). The agreement between the proposed standards and the research and farm measurement data encourage confidence in the approaches used and in the NARSES estimates of gaseous N losses from manures following excretion.

Software development and operation

The software tool has been developed as a standalone desktop application suitable for use on Windows® 2000 and Windows® XP operating systems. The application contains a core calculation component written as a Dynamic Link Library (DLL). This DLL calculation component has been incorporated into a user-friendly interface and may also be integrated into other software applications. User entered data are stored in a simple Microsoft® Office Access database. A similar technique was used very successfully in the PLANET Nutrient Management Decision Support Software (Dampney and Sagoo, 2008).

The software allows selection of livestock production systems and information is collected via a number of simple data input fields. Following initial user feedback during the development of the tool, a facility has been provided where the user may elect to use default values provided by the software. These may be edited later if farm-specific information is available.

The user may save information entered to a database and produce a report showing input data and the N and P balance estimate. A simple help file has been developed which provides guidance on the use of the software and information on the data required by the tool. A short written document has also been prepared to guide the first-time user of the software.

Studies in the UK have suggested that farmers will use decision support software only where the required input information is simple and easily available (Smith *et al.*, 1997). In the early stages of the development of ENCASH, a small 'stakeholder' group consisting of farmers (dairy and pig sectors represented), consultants and policy advisers from Defra and Natural England, were consulted regarding design, operation and reporting of ENCASH. A further workshop, in the latter stages of the project, provided further reinforcement of the adopted approaches.

After the initial splash screen (Figure 2 (a)), a 'wizard' type approach (Figure 2 (b)) is taken to guide the user to setting up their basic farm information data. On successive screens in the wizard the user is asked to select their livestock enterprise(s) and enter relevant farm data.

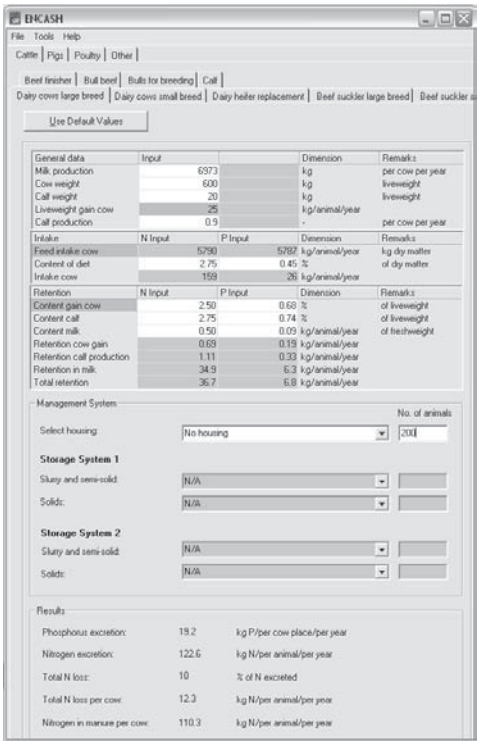
On leaving the wizard, the user is taken to an area of the application where detailed entry screens appear only for those livestock categories chosen in the wizard. Here the user enters information about the livestock enterprise(s), including animal types, numbers, housing, manure management system (slurry, FYM, litter), including storage. The screens are divided into two main areas – the data entry and, below, the results section (Figure 3). The user cannot edit the results area of the screen which updates dynamically with each item of data entered.

Figure 2. Start-up and wizard

(a)

(b)

Figure 3. Livestock data entry screens and summary output on N and P output



ENCASH requires only inputs that are readily available to farmers or their consultants. To assist the user during data entry, for inputs that may be less readily available, default values are provided for these fields - for example calf weight, cow liveweight gain, feed intake; these defaults being based on “typical” industry practice. The software also incorporates defined acceptable ranges for input parameters and extensive logic checks to disqualify illegal or nonsensical entries, or to advise the user of atypical values.

The software similarly allows only the choice of real housing or manure management/ storage systems, these options being stored in a series of system matrices, for cattle, pigs, poultry and “other livestock” categories. Only classes of stock and manure management found in current UK production systems are included. Also, the matrices store the calculated N emission factors (EF) imported from the NARSES model, which are used for the discounting of N following excretion and in calculation of the manure N output for the farm. The overall estimated N loss, as a percentage of total N output and on a per animal/ bird basis, is displayed in results section, together with calculated N and P output

Conclusions

A decision support system has been developed which is capable of calculating livestock manure N and P output on an individual farm basis based on simple input values. The software is capable of dealing with most livestock enterprises and it should assist producers in improving the efficiency of their system by means of scenario testing.

Data input values are those which should be known to farmers or their consultant and, where not known, typical standards are given. These are based on published data and gaps in these data have been supplemented by expert knowledge on typical industry practice. An associated report and technical user guide covers the detail of software development, with background information on default values and guidance on appropriate adjustments.

ENCASH is a potentially valuable aid to providing farm specific information on N and P outputs and to assist farmers in meeting the requirements of the NVZ Action Programme. Initial user testing by consultants has been positive, with no significant software problems. It is anticipated that ENCASH will find wide application throughout the farming community particularly with consultants and farm business managers.

Acknowledgement

Funding for the development of the ENCASH software tool, from the Department for Environment, Food and Rural Affairs (Defra), is gratefully acknowledged.

References

Anon. (2002). European Commission. Nitrogen Equivalents in Livestock Manures. Luxembourg: Office for Official Publications of the European Communities, ISBN 92-894-1277 1

Anon. (2007). The protection of waters against pollution from agriculture; consultation on the implementation of the Nitrates Directive in England. Aug 2007. Available via the Defra website: http://www.defra.gov.uk/corporate/consult/waterpollution-nitratres/index.htm

Cottrill, B.R., Smith, K.A., Agostini, F.A. and Silgram, M. (2005). Evaluation and control of nutrient excretion in livestock manures. Paper to EC workshop, Brussels, Feb 14, 2005.

Cottrill, B.R. and, Smith, K.A. (2007) Nitrogen output of livestock excreta. Support paper F2. Available via: http://www.defra.gov.uk/corporate/consult/waterpollution-nitratres/index.htm

Dampney, P.M.R. and Sagoo, E. (2008). PLANET – The national standard decision support and record keeping system for nutrient management on farms in England. In: Agriculture and Environment VII - Land Management in a Changing Environment (Eds. K. Crighton and R. Audsley) Proceedings of the SAC and SEPA Biennial Conference. pp239-245.

Ketalaars, J.J.M.H. and van der Meer, H.G. (2000). Establishment of criteria for the assessment of the nitrogen content of animal manures. Final report to ERM, carried out on behalf of DG XI of the European Commission.

Laws, J., Smith, K.A., Cottrill, B. and Dewhurst, R. (2004). Impact of nutrition and management on N and P excretion by dairy cows. Final project report, Defra contract NT2402, available via Defra website: http://www.defra.gsi.gov.uk

MAFF. (1990). UK tables of nutritive value and chemical composition of feedingstuffs. Ed. D. I. Givens. Published by Rowett Research Services, Ltd, Buckburn, Aberdeen.

Maynard, L.A. and Loosli, J.K. (1969). Animal Nutrition. McGraw-Hill, New York, 361-362; 472-473.

Misselbrook, T.H., Chadwick, D.R., Chambers, B.J., Smith, K.A., Williams, J and Demmers, T.G.M. (2007) Inventory of ammonia emissions from UK agriculture 2006. Defra Contract AC0102, November 2007, 35pp. Available via Defra website: http:// www.defra.gsi.gov.uk

Scholefield, D.,Lockyer, D. R., Whitehead, D. C., Rodda, H. J. E. (1991) A nitrogen-cycle model to predict nitrogen losses from grazed grassland. Proceedings of Operational Research Society Study Group Meeting on "Modelling Approaches to the Control of Agricultural Pollution". Silsoe Research Institute.

Smith, J.U., Dailey, A.G. et al….. (1997). Constructing a nitrogen fertiliser recommendation system using a dynamic model; what do farmers want? Soil Use and Management 13, 225-228. Webb, J., Misselbrook, T.H., 2004. A mass-flow model of ammonia emissions from UK livestock production. Atmospheric Environment 38, 2163-2176.